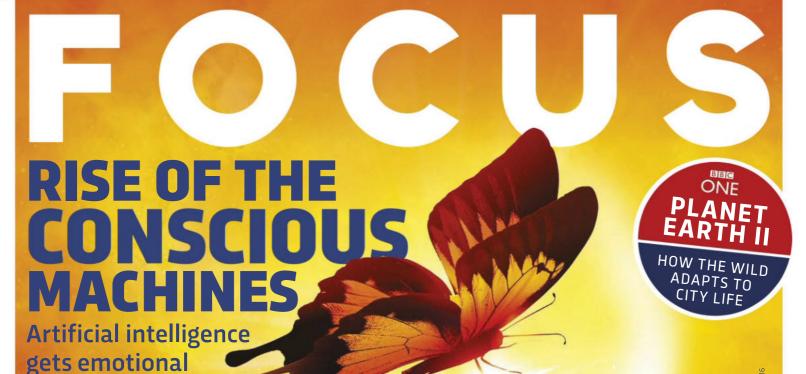
BBC

SCIENCE AND TECHNOLOGY





WHAT MAKES BATTERIES EXPLODE?

WHAT TIME IS IT ON THE MOON?

DOES CHICKEN SOUP HELP A COLD?

THE SEARCH FOR A SECOND SUN

Plus 9 radical ideas from science's boldest minds



MARS MINER

THE BEST VR

THE REAL

JURASSIC PARK

De-extinction demystified

HEADSETS







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*This camera's built-in Bluetooth® capability can only be used with compatible smart devices. The Nikon SnapBridge application must be installed on the device before it can be used with this camera. For compatibility and to download the SnapBridge application, please visit Google Play® and App Store.



WELCOME



We tend to talk about artificial intelligence as though it's some blurry vision of the future, yet to sharpen into focus. But the reality is it's already here, and it's already wormed its way in to our everyday lives.

Online strings of code follow our every click, logging and learning what we like and what we don't. Facebook does it to show us only the posts it hopes we'll enjoy, Google does it to offer up what it thinks

we're looking for, and who hasn't bought something that Amazon thought we might like?

These algorithms – sets of step-by-step mathematical instructions for computers – are becoming more and more sophisticated, less machine, more human. Digital assistants such as Siri, Alexa and Cortana from Apple, Amazon and Microsoft respectively, can now understand our natural language and answer our questions to a degree. And again, every request is inputted into a 'deep learning' system that trains each assistant to better meet our needs in future. Even their voices are meticulously designed to make us happy.

But how are we going to get from here to the AIs we know and love? For better or worse, how do we build the fluent, intuitive, almost human machines of science fiction? We need to add a little something extra: find out what on p40.

Daniel Bennett

Daniel Bennett, Editor

IN THIS ISSUE



FREDI DEVAS

New series *Planet Earth II* comes to our television screens this winter after five years in the making. Fredi, one of the series' producers, shares some of his incredible experiences creating this show. → p52



PROF JIM DUNWELL

Jim is a professor at Reading University's School of Agriculture, Policy and Development, with a particular interest in plants. In this issue he asks if it is time we got over genetically modified food. → p78



PROF KATHY WILLIS

Love Kew Gardens? Meet Kathy, the director of science at this stunning attraction. This month, she tells us what her job entails and reveals some of the intriguing plants she gets to research. → p130

WHAT WE'VE FOUND OUT THIS MONTH

800% MORE

GLYPHOSATE HERBICIDE

mumm

In the US, eating only

GM-free food would increase the average food

bill by a third

→ p85



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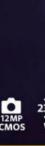
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Brings you closer



FOCUS DECEMBER 2016 CONTENTS









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Should we invent human like robots, with the ability to think, feel and empathise like us?

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Feast your eyes on some of the incredible wildlife that's setting up home in the concrete jungle.

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Plus nine more of the strangest theories that scientists are researching right now.

72 The real Jurassic Park Once a species has gone extinct,

Once a species has gone extinct that's it, right? Not necessarily, says Helen Pilcher.

$78 \, \text{Should we get} \\ \text{over GM food?}$

Many people are opposed to genetically modified foods. But are their fears justified?













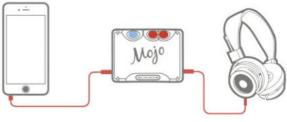




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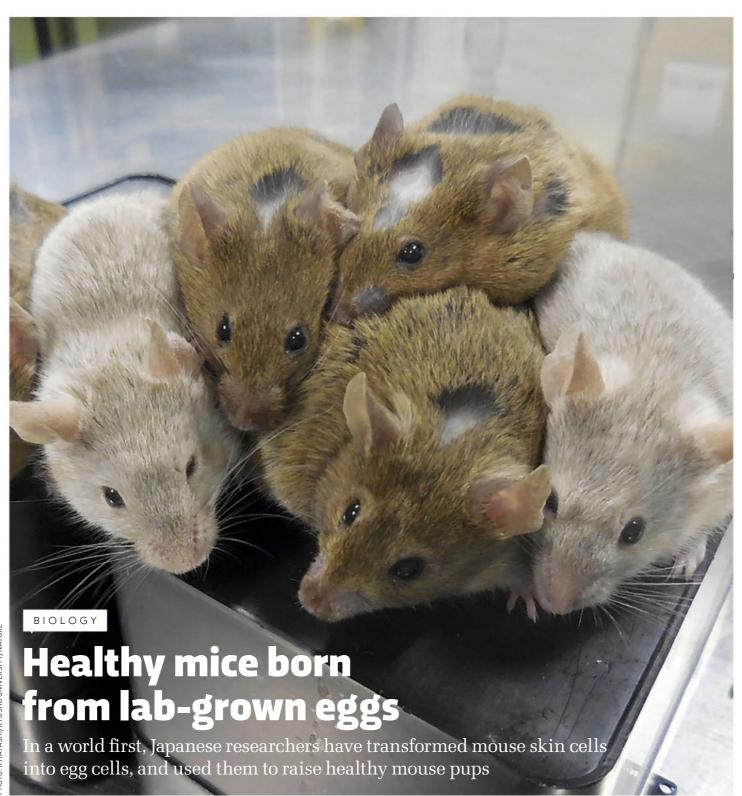






DISCOVERIES DISPATCHES FROM THE CUTTING EDGE

DECEMBER 2016 EDITED BY JASON GOODYER



HOTO: K HAYASHI/KYUSHU UNIVERSITY/NATURE

The team, led by Katsuhiko Hayashi at Kyushu University, took skin cells from the tips of the tails of adult mice and transformed them into induced pluripotent stem cells. These are cells that have been genetically modified to behave like embryonic stem cells, which are capable of forming any adult cell type.

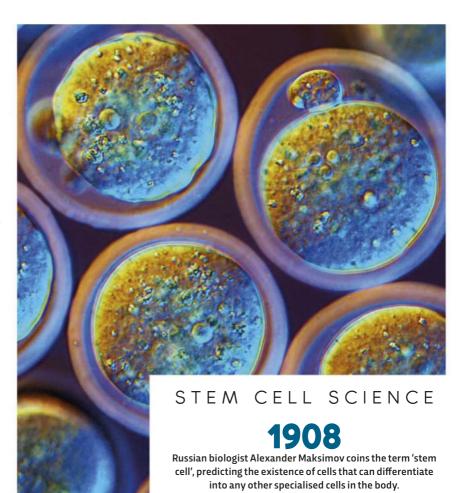
To coax the stem cells into growing into eggs, the researchers treated them with growth factors and hormones taken from mouse ovaries. The eggs were then fertilised using established IVF techniques, before being implanted into the wombs of living mice. "This is the first report of anyone being able to develop fully mature and fertilisable eggs in a laboratory setting right through from the earliest stages of oocyte [egg cell] development," said reproduction expert Richard Anderson, from the University of Edinburgh, who was not involved in the research. "One day this approach might be useful for women who have lost their fertility at an early age, as well as for improvements in more conventional infertility treatments."

The method's far from perfect. Only 11 of the 300 embryos implanted resulted in successful births. What's more, many of the artificially produced eggs showed slight differences in gene expression from their naturally produced counterparts, suggesting they develop slightly differently.

The next step is for other teams to repeat the result, perhaps in animals such as pigs or sheep, to confirm its validity. But debate of the ethics of using the technique in humans should begin now, says the University of Cambridge's Azim Surani.

"Ethically, this issue has yet to be discussed fully by the scientists and society. These discussions have occurred in the past, and are continuing within the regulatory bodies, certainly in the UK," he said. "This indeed is the right time to start a debate and involve the wider public in these discussions, long before and in case the procedure becomes feasible in humans."

"THIS APPROACH MIGHT BE USEFUL FOR WOMEN WHO HAVE LOST THEIR FERTILITY AT AN EARLY AGE"



ABOVE: Fertilised mouse egg cells

1978

Gregor Prindull and colleagues discover haematopoietic stem cells, those that can differentiate into all kinds of blood cells in the body, in the blood of the umbilical cord.

1998

A team led by James Thomson at the University of Wisconsin-Madison collect pluripotent stem cells, those that can differentiate into nearly all kinds of cells, from a human embryo.

2005

Researchers at Kingston University and the University of Illinois discover pluripotent stem cells in umbilical cord blood.

2007

Kazutoshi Takahashi and Shinya Yamanaka of Kyoto University, as well as researchers from James Thomson's lab, transform human muscle cells into pluripotent stem cells.

2013

Will Shu's team in Heriot-Watt University develops a 3D printer that uses pluripotent stem cells as building blocks.



SPACE

Was a comet responsible for the formation of the Stickney Crater, seen here on the right of Phobos?

This is how Mars' biggest moon came to look like the Death Star

Thanks an enormous ding on its surface known as the Stickney Crater, Mars' moon Phobos is said to look like the Death Star from the *Star Wars* movies. The crater is presumed to have been caused by comet impact, but exactly how a 9km-wide crater could have formed on a 22km-wide moon without destroying it has remained something of a mystery.

Now researchers at Lawrence Livermore National Laboratory think they have the answer. Using computer simulations, they found that the most likely culprit was a comet with a 250m diameter, travelling at close to six kilometers per second.

Previous studies using 2D simulations lacked the resolution to model the Stickney Crater successfully and failed to account for the fact that Phobos is made of much less dense material than its host planet.

"We've demonstrated that you can create this crater without destroying the moon if

you use the proper porosity and resolution in a 3D simulation," said researcher Megan Bruck Syal. "There aren't many places with the computational resources to accomplish the resolution study we conducted."

As well as solving a longstanding mystery, this research also acts as a proof of concept exercise for the team's modelling software, Spheral, which they use to simulate various methods of deflecting potentially hazardous Earth-bound asteroids. "Something as big and fast as what caused the Stickney Crater would have a devastating effect on Earth," Syal said. "If NASA sees a potentially hazardous asteroid coming our way, it will be essential to make sure we're able to deflect it. We'll only have one shot at it, and the consequences couldn't be higher. We do this type of benchmarking research to make sure our codes are right when they will be needed most."

IN NUMBERS

81,000 YEARS

The time it takes asteroid impacts to completely change the surface of the Moon, according to a seven-year study carried out at Arizona State University.

122

The age of Jeanne Calment when she died in 1997, making her the oldest person to ever live on official record. Results from a global study from the Albert Einstein College of Medicine, New York, suggest this may be near to the maximum age a human can ever reach.

2 TRILLION

The number of galaxies in the observable Universe, as estimated using data taken from the Hubble Space Telescope. The figure was previously thought to be 10 times smaller.

SPACE

NASA'S MINING BOT GETS ROLLING

We definitely dig this. NASA has started testing the Regolith Advanced Surface Systems Operations Robot (RASSOR). This robot is designed to mine resources on the surface of asteroids, the Moon or even Mars.

The bot is in development at Kennedy Space Center in Florida. The agency has released a video showing a simulated mission in which RASSOR was used to scoop up regolith, which is the loose, rocky material on the surface of a planet. It then loaded the regolith into a device called a MARCO POLO/Mars

utilisation system. This pulls water and ice out of the regolith and turns their chemicals into fuel or air for astronauts working on the surface.

The primary challenge for any digging robot operating in low gravity is that it has to be light and small enough to fly on a rocket, but heavy enough to operate in gravity lower than Earth's. RASSOR tackles this problem by using digging bucket drums at each end of the robot's body that rotate in

opposite directions,

to let the opposite side dig into the soil. It has a top speed of 4cm per second, five times faster than the Mars Curiosity rover, and is capable of hauling around 20kg of material.

"[On Mars] there are some areas at the poles where they think there's a lot of ice, so you'd be digging in ice," said NASA engineer AJ Nick. "There's other areas where the water is 30cm down, so you actually have to dig down 30cm and take off the top and that depth is really where you want to start collecting water ice."

To see the RASSOR in action, visit



NEUROSCIENCE

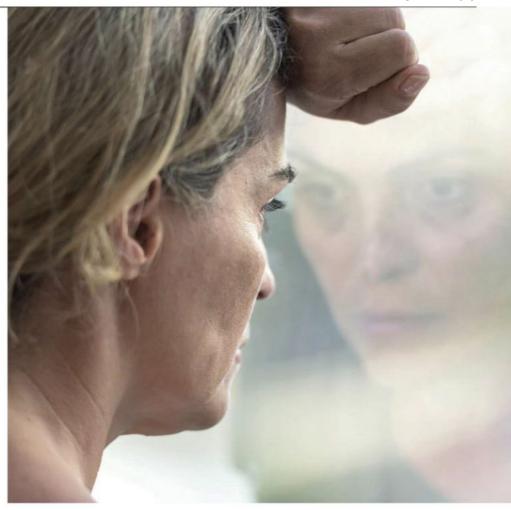
PHYSICAL ROOT OF DEPRESSION FOUND IN BRAIN

It seems abnormalities in grey matter may lead to black moods. A team based at Warwick University and China's Fudan University has found evidence that depression has a physical root in the brain.

The findings could lead to new treatments for depression by targeting the root cause of the illness and helping depressed people to stop focusing on negative thoughts, the team said.

"More than one in ten people in their lifetime suffer from depression, a disease which is so common in modern society and we can even find the remains of Prozac – a depression drug – in the tap water in London," said researcher Jianfeng Feng. "Our finding enables us to locate the roots of depression, which should open up new avenues for better therapeutic treatments in the near future for this horrible disease."

After using high-precision MRI to scan the brains of nearly 1,000 volunteers, half with depression and half without, the team found that the medial and lateral orbitofrontal cortexes, areas of the brain associated with emotion and reward, are wired up differently in those suffering from depression.



The lateral orbitofrontal cortex is activated during feelings of disappointment such as when expected rewards are not received. The researchers found that in depression sufferers it is more closely connected to areas of the brain involved in one's sense of self, and so could therefore explain

their negative self-perception and lower self-esteem.

They also found reduced connectivity between the reward brain area in the medial orbitofrontal cortex and memory systems elsewhere, meaning depression sufferers are less likely to recall happy memories.

THEY DID WHAT?!

SCIENTISTS SEARCH FOR REGIONAL ACCENTS IN COD

What did they do?

A team at the University of Exeter eavesdropped on the conversations of cod.

Why did they do that?

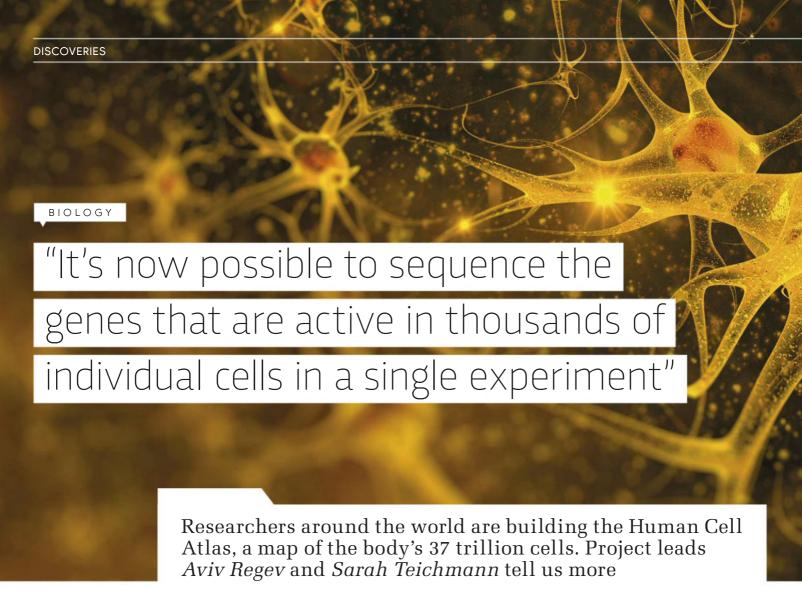
They were looking for regional differences in the sounds that fish make to establish territories, raise the alarm and attract

mates. If separate populations communicate differently, fish meeting for the first time due to climate change driven migrations may struggle to hit it off with their new neighbours.

What did they find?

American cod make a "staccato, banging, bop bop bop sound" while European cod make a "deep rumbling growling". The difference is thought to be due to localised breeding grounds being established for thousands of years, leading to regional accents.



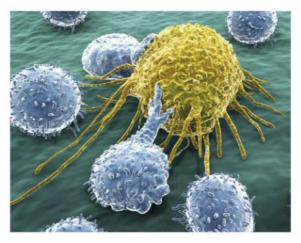


How many different types of cell are there?

Textbooks will tell you 200 to 300. But just in your retina there are about 100 different types of neurons – some are like detectors in a camera, some notice when lights turn on or off, others when there's motion. While the number in a textbook is right at a high level, the finer distinctions matter a great deal.

How do you distinguish between cells?

The new tool that we're tremendously excited about is 'single-cell genomics'. It's actually possible to



RIGHT: The Human Cell Atlas will help us decipher cancer cells (yellow), to develop better treatments sequence [read the DNA of] the genes that are active in thousands of individual cells in a single experiment. We have all these different types of cells but they all have roughly the same genome, and the difference between them is which genes they turn on and off. Before, we had to look at millions of cells together and take an average, which basically didn't represent any given one of them. Now we can look at every individual cell.

How will you build a map of cells?

The location from where a sample is taken positions it. There's a second, microscopic-scale method that allows you to place cells spatially in relation to each other. We like to say that you need to 'know thy cells' but you also need to 'know thy neighbour'. Who the cells can actually talk and listen to, and affect, really matters for how our tissues work when we're healthy, and how they break down when we have a disease.

Why do we need the Human Cell Atlas?

There is a basic, fundamental question of knowing exactly what we're made of. Part of science is just discovering and understanding more about ourselves. But it also gives the people on the front



ABOVE: In your body, there are hundreds of types of cells. The Human Cell Atlas will chart the properties of every single one of them lines of disease, those who develop drugs and physicians who diagnose patients, something they did not have before.

With cancer, tumours are actually made of many different kinds of cells. They include malignant cells, which are the actual cancer. But these are not all the same because there are different mutations in the genome. Yet there are many other cells inside the tumours. This gives us amazing opportunities to try and manipulate the non-cancer part, to make it not as hospitable to the tumour. That's something called immunotherapy, where you're targeting the immune cells and making them attack the tumour.

When will the project be complete?

We're at a pilot phase, starting on both technical pilots and specific organs. It depends on how you define completion exactly, but we might have a draft in a five years' time and a really accurate map in 10 years' time. Remember that geographical maps are a matter of resolution too: think of a map of England in 1500; now you have GPS and the precision of Google Maps. So as we proceed in the project, the picture sharpens. But even the slightly fuzzier images you get in the beginning are still unprecedented and enormously useful.



ACNE SUFFERERS

Having spots in your teens may mean living late into old age. A team at King's College London has found that acne sufferers have longer telomeres. These structures, found on the end of chromosomes, reduce the DNA deterioration associated with ageing.

LORRY DRIVERS

Ordnance Survey is producing an updated road database with the aim of reducing the number of HGVs getting stuck under bridges. Good news for traffic flow, though it might mean fewer bridge vs lorry videos for the rest of us to snigger at.

GOOD MONTH

BAD MONTH

ARACHNOPHOBICS

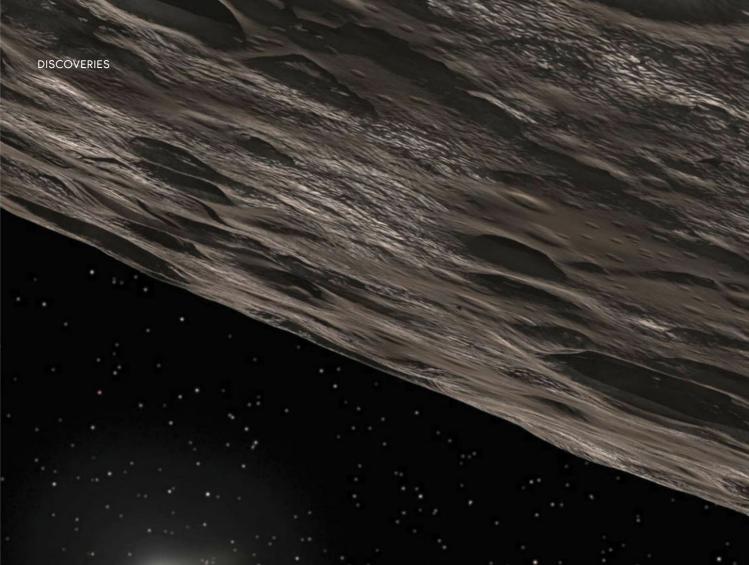
Researchers at Cornell University have found that jumping spiders have an incredible sense of hearing despite lacking eardrums. The spiders were able to hear sounds over three metres away, so please try to be considerate when screaming.

ONLINE TROLLS

The Crown Prosecution Service has published new social media guidelines to combat cyber crime such as online harassment and cyber stalking.

Looks like it might be time for some to go back under their bridges...





SPACE

NEW DWARF PLANET DISCOVERED AT THE EDGE OF THE SOLAR SYSTEM

Pluto has a new buddy: astronomers at the University of Michigan have spotted a new dwarf planet lurking in the outskirts of the Solar System.

Dubbed DeeDee, short for 'distant dwarf', the planet is between 320km and 1,290km in diameter and is currently more than 13.6 billion kilometres from the Sun, making it the one of the most distant minor planets ever seen.

It was found using DECam, a powerful digital camera on a four-metre telescope in Chile that's capable of picking up extremely faint signals. The reflected sunlight detected from DeeDee is as dim as the light from a single candle observed from 160,000km away.

The researchers say the discovery of this icy, faraway world shows that their method has potential for finding Planet Nine – a massive

body hypothesised to reside around 600 times farther from the Sun than Earth does.

"The discovery of DeeDee is a promising sign of our ability to find distant new worlds," explained lead researcher David Gerdes. "If more things like this are in our data, the tools we've built will find them."

To identify the planet, the team fed thousands of images into a computer programmed to find objects moving in orbit around the Sun, against the background of millions of stars and galaxies that remain in the same place from night to night.

"Every image taken by DECam is subtracted from every other image from the same piece of the sky. That way, we can find moving Solar System objects even if they happen to lie right in front of a background galaxy or star," said researcher Masao Sako.

MATERIALS

GRAPHENE-MUNCHING SILKWORMS SPIN 'SUPER SILK'

If you want your silkworms to spin super-strong silk, just feed them graphene.

Researchers at Tsinghua University in China have found that spraying a solution containing 0.2 per cent graphene or carbon nanotubes (basically rolls of graphene) onto a silkworm's regular diet of mulberry leaves causes them to spin silk that is 50 per cent stronger than usual.

After putting the silk into a spectrometer, the team found that the 'super silk' had a more orderly structure than regular silk with parts of the fed carbon nanomaterials incorporated into the fibres. This graphite-like structure also allows the fibres to conduct electricity.

The team are as yet unsure how the carbon materials made it into the silk but say the process could be scaled up to produce large batches. It could potentially be used to make eco-friendly protective fabrics, stronger medical implants or wearable electronics, they say.



ABOVE: Adding carbon nanotubes (pictured) or graphene to a silkworm's diet allows them to create stronger silk



WHAT WE LEARNED THIS MONTH

DINOSAURS DIDN'T ROAR

The T. rex just got a little less terrifying. A team at the University of Texas has found that rather than roaring, dinosaurs made a honking sound similar to that made by geese.

CHEESE MAKES WINE TASTE BETTER

Want to hide the fact you are serving your dinner guests cheap plonk? Break out the brie. Researchers at the Centre for Taste and Feeding Behaviour in Dijon have found that drinking wine after eating cheese increases the aroma of red fruits and reduces the astringency caused by tannins.

ASTRONAUTS FACE DEMENTIA RISK EN ROUTE TO MARS

Prolonged exposure to energetic charged particles, such as those found in cosmic rays, could cause significant long-term brain damage resulting in cognitive impairments and dementia, researchers from the University of California have found.

ELEPHANTS WALK ON THEIR TIPTOES

What do elephants and ballerinas have in common? They both walk up on their toes. Researchers at the University of Queensland have found that elephants put most pressure on the outside toes of their front feet as they plod around.

PHOTOS: NASA, GETTY X2



BUGGIN' OUT

Creepy crawlies played a prominent role in this year's Nikon Small World photomicrography competition. Here are some of our favourites...

1. EYE SPY

Of the Adanson's jumping spider's eight eyes, the two large ones red stinging ants in seen here have the sharpest vision. They contain four sets of light-sensitive cells that let the spider see in and an adult insect. 3D. By comparing the images resolved on able to figure out how far away an object is.

2. CHEEK **TO CHEEK**

Snuggled together here are a pair of European pupal form, which is the state of development that occurs between a larva Their exoskeletons are yet to harden, giving each layer, the spider is them this characteristic pale and translucent appearance.

3. FUNKY **FOOT**

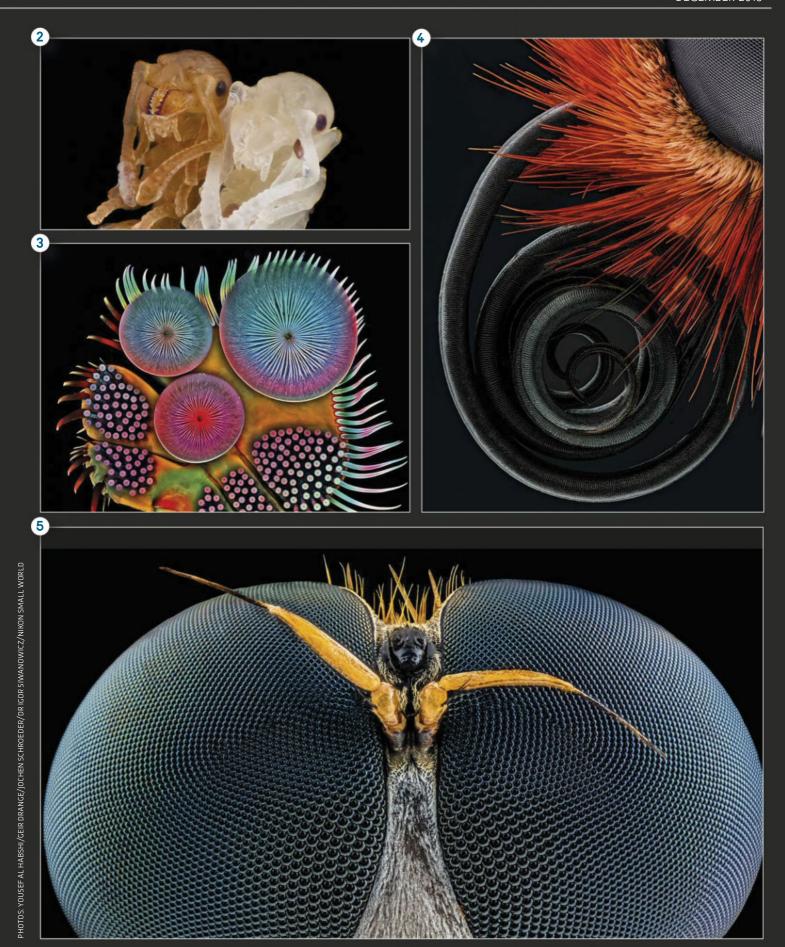
This kaleidoscopic appendage belongs to a male lesser diving beetle, which is an insect that's found in bogs, ponds and streams across northern Europe. The three large circular suckers are used by the male to attach to the slippery carapace of the slurp up the sugary female during mating.

4. TONGUE TWISTER

When a butterfly gets a bit thirsty, all it has to do is unfurl its proboscis, shown in this image, and head to the nearest flower. The coiled organ acts like a drinking straw, enabling the insect to reach deep within the petals of a flower and nectar found within.

5. TINY DANCER

Look closely at this image of a wasp's head and an eerie sight emerges: a ghostly figure appears to be dancing in the space between the two bulbous domes that make up the insect's compound eyes. The 'face' is made up of the ocelli, simple eyes also seen in slugs and snails.





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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

DECEMBER 2016 EDITED BY RUSSELL DEEKS

LET THE CYBER GAMES BEGIN!

On 8 October, the city of Zurich in Switzerland played host to the first ever Cybathlon, which saw disabled athletes from around the world competing against each other. Unlike the Paralympics, though, the Cybathlon is as much about showcasing technologies such as prosthetics and robotics as it is about winning medals. One event, for instance, saw paraplegics competing in a specially designed

computer game using braincomputer interfaces, as shown by Sebastian Reul of German team Athena-Minerva in this image. Another event involved bicycles that could be pedalled by someone with no movement in their legs, using a technology called functional electrical stimulation. There were also more familiar races for those with prosthetic arms or legs, and for wheelchair users.





PHOTOKINA 2016

The best cameras from Europe's biggest photography show...

1. GOPRO HERO5 BLACK

GoPro's action camera is now fully waterproof. It offers voice control in seven languages, plus 12MP resolution, 4K video at 30fps and a two-inch touchscreen. For tighter budgets, £250 will get you the touchscreen-less GoPro Hero5 Session. £350, qopro.com

2. OLYMPUS OM-D E-M1 MARK II

This beauty has a 20.4MP sensor and a five-axis image stabilisation system. It can shoot full-res images at 60fps in autofocus mode, or at 18fps with continuous tracking, making it a perfect package for wildlife or sports photographers. £TBC, olympus.com

3. HASSELBLAD V1D

This 75MP concept from Hasselblad adopts a modular approach, enabling you to accessorise with screens, viewfinders, grips and other parts – something that could be useful for left-handed snappers. *EN/A, hasselblad.com*

4. LEICA SOFORT

Instant photography's all the rage, and high-end manufacturer Leica is getting in on the act with this feature-packed camera that gives you an optional built-in flash, a choice of eight different shooting modes and an LCD screen on the back.

£230 approx, leica-camera.com

5. PANASONIC LUMIX G85

This 16MP cam has a tilt-and-swivel three-inch display, OLED electronic viewfinder and five-axis image stabilisation. It'll shoot 4K vids at 30fps (or 1080p video at 60fps), but the price given is for the body only. \$900 (£736 approx), panasonic.com

6. SONY ALPHA A99 II

This 42.4MP DSLR is Sony's first to shoot 4K video. The auto-focus system lets you shoot crisp images in continuous shooting mode at 12fps. With its 1,204 x 768 OLED viewfinder and max ISO of 102,400, you're looking at a serious bit of kit.

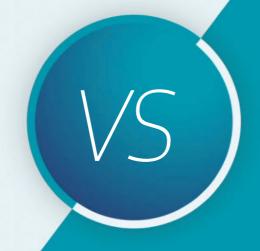
€3,600 (£3,250 approx), sony.co.uk

iPHONE 7

Apple's latest update is a less radical upgrade than in previous years, and the disappearance of the headphone jack has caused consternation. On the plus side, the camera is a big selling point with its twin wideangle and telephoto lenses, while other key improvements include stereo speakers and a 25 per cent brighter Retina display. Those things plus brand loyalty mean it shouldn't bomb – but can it retain its market-leading position?



iPHONE 7	IPHONE 7 PL
iOS 10	iOS 10
4.7 INCH	5.5 INCH
750 x 1,334	1,080 x 1,920
2GB	3GB
32 256GB	32 256GB
12MP, F/1.8	12MP, F/1.8
2,160P	2,160P
14HRS	21HRS
NO	NO
£600	£720
	iOS 10 4.7 INCH 750 x 1,334 2GB 32 256GB 12MP, F/1.8 2,160P 14HRS NO



	PIXEL	PIXEL XL
OPERATING SYSTEM	ANDROID 7.1	ANDROID 7.1
SCREEN SIZE	5-INCH	5.5-INCH
SCREEN RESOLUTION	1,080 x 1,920	1,440 x 2,560
RAM	4GB	4GB
ONBOARD STORAGE	32-128GB	32-128GB
CAMERA	12MP, F/2.0	12MP, F/2.0
VIDEO MAX RES (30FPS)	2,160P	2,160P
TALK TIME	26HRS	32HRS
HEADPHONE JACK	YES	YES
PRICE (32GB)	£600	£720

When you stack the specs side-by-side, the Pixel nudges ahead of the iPhone in most departments, but it's a close call. So the Pixel's real selling points are a camera that's being touted by Google as "the best phone camera ever", and Google Assistant. This replacement for Google Now reflects the fact that Google's banking heavily on AI being the next big tech wave. Whether Google's right, of course, remains to be seen.









GO PRO

FENDER FXA2

These earbuds from Fender are designed for on-stage use as in-ear monitors by pro musicians. But there's absolutely no reason why you can't use them for listening to music – why should musos get all the benefit of the -22dB noise reduction and custom Fender-built 9.25mm drivers? They're available in a choice of colours, and of course you (or rather your ears) get to swank about sporting that famous logo...

£129, fender.com



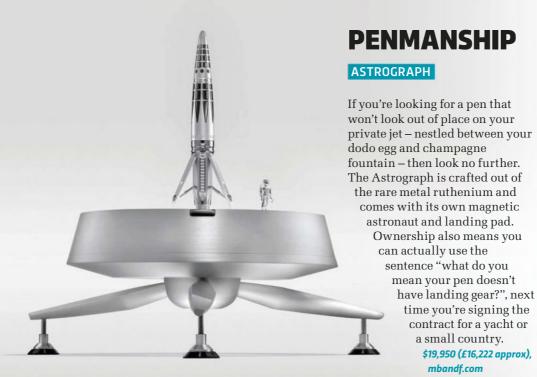
AS LONG AS YOU'VE GOT YOUR ELF...

ROBELF SECURITY ROBOT

At 850mm tall, this is no Robocop. Nevertheless, this cute bot has been built with home security in mind, and will patrol your house while you're out. It uses face recognition software and a 5MP Elf Eye camera to detect intruders, and will return automatically to its charging station when necessary. Robelf responds to voice commands, and the camera also comes with a docking station so you can use it as a simple webcam.

\$530 (£430 approx), robelf.com





APP FEED



Star Wars StudioFX

This free app from Hasbro lets you add special FX such as explosions and lasers to stop-motion videos made using toys. Free, iOS/Android





Stephen Hawking's Pocket Universe

Explore the cosmos with the famous physicist, using what's essentially the app version of *A Brief History Of Time*. £5.99, iOS





Fotr

A camera app with an old school twist: buy a 'roll of film', take your 24 or 36 shots and get your photos through the door 10 days later! Hang on, haven't we been here before? Free, iOS





With all the VR devices out there, it can be difficult to know where to start. Let tech guru **lan Evenden** be your guide



HTC VIVE

The Vive has been developed as a partnership between electronics manufacturer HTC and videogame maker/seller Valve. It offers room-scale VR for the PC, thanks to a pair of base stations that you mount onto the walls of the room you're going to use it in. They track the movement of the player, who controls the game via two wireless, motion-sensing controllers.

Integration with the real world, through links to your phone for messages plus a front-facing camera, mean you never feel cut off and are less likely to fall over the coffee table.

As with the Oculus Rift, you'll need quite a powerful PC to play VR games. A GeForce GTX 970 or AMD R9 290 is the minimum graphics processor supported, along with a recent quad-core CPU.

£759, vive.com

OCULUS RIFT

Facebook-owned Oculus VR has been a standard-bearer for the new wave of head-mounted VR displays on the PC. With the upcoming launch of its Touch controllers, it's also the first system to get an upgrade.

Previously, Rift games have been played with an Xbox One controller from Microsoft; while these are great gamepads, they're not kitted out to track the movement of your hands. The Rift's new controllers allow it to catch up in this area.

The Rift offers head-tracking through a sensor that stands on your desk, but the need to remain seated in front of it means there's no following of your body movements. Despite this, the Rift feels like a complete VR package, just one that may need another upgrade in the future.

5798 (£650 approx), oculus.com





RAZER

Razer, in partnership with VR firm Sensics, is building a headset based on the Open Source VR Project. This is an attempt to free virtual reality from the domination of major tech companies and create an open standard around which hardware and software can be developed. Using the OSVR software development kit, all hardware on the market can be supported by software makers.

Its headset, the Hacker Dev Kit, is similar in specs and looks to the Rift and Vive, connecting to your PC via USB and HDMI. A software plugin lets it work with games from the Steam store.

The Hacker Dev Kit, as suggested by its name, is perhaps best for those who really know what they're doing. It's an exciting idea, though, that could open up virtual reality to all customers.

£400, razerzone.com/gb-en



DAYDREAM

VR that uses a smartphone in a headset has been around for a while in the form of the Gear VR, but Google has recently announced its Daydream device, the software for which will be built into Android phones running version 7.1 or later of the operating system.

Daydream is platform-agnostic, unlike Gear which requires a Samsung handset. Phones will need certain hardware features, such as nine-axis motion sensors and low-energy Bluetooth, to be compatible with the headset, which will come packaged with a wireless controller. Its low price is due to it being made out of cloth – a step up from the Google Cardboard headset that was the firm's first foray into smartphone VR. Games, movies and other content will come from the Google Play Store.

£69, vr.google.com





HOLOLENS

Microsoft's head-mounted display looks different to all the others, being more like a set of smart glasses than an all-enveloping helmet. The Hololens acts differently too, mixing VR with reality rather than replacing it completely. It also contains powerful processors in the headset itself, rather than relying on the host PC.

The current version is aimed at software developers rather than consumers, and is both expensive and lacking in software support. But there is a version of *Minecraft* that allows you to play the block-building game on your kitchen table, while a 3D-modelling program can output to a 3D printer.

Hololens may not be the best way to experience VR, but it could offer a glimpse at the future of computing. \$3,000 (£2,451 approx), microsoft.com/microsoft-hololens

PLAYSTATION VR

Sony's recently launched PlayStation 4 add-on could be the release that launches VR into the mainstream. It requires a £250 console to play on and software support is currently a little limited, but it should ramp up over the coming months. Although Sony recommends that players remain seated while playing, the PlayStation Camera is capable of motion tracking over an area of about three metres by two metres, as along as you remain 0.7m away from the camera. Therefore, make sure you've got enough space when you start playing games that require movement.

The PSVR is user-friendly and easy to set up, when compared to PC-based VR systems. It's the only place you'll get to be Batman too, as Rocksteady's *Arkham VR* is a title exclusive to the platform.

The PlayStation system is capable of displaying on a television as well as in the headset, allowing VR and non-VR players to play together.

£350, playstation.com

THE FAST TRACK

Daniel Bennett tests two of this year's smartest cars to find out how technology is shaping our future drives

The new Mercedes E-Class is dripping with gadgets. Touch-sensitive pads on the steering wheel control your 'infotainment system', displays offer customisable dashboards and you can even choose from 64 colours for your interior lighting on the fly (we went for *Tron* blue). But that's not what makes this car interesting.

This Mercedes cares about you, a lot. Not only does it want you to get from A to B safely, but it wants to help you get there with minimal effort. In fact, if we were to give the car a name, we'd call it Alfred. This is just the net effect of Mercedes' 'Intelligent Drive' system, which is the name given to the car's safety and assistance features. On the road, 360° cameras and radar keep a watchful eye. These sensors also enable the car to take care of the driving on a motorway, though you need to keep your hands on the wheel at all times. Get into traffic and it'll free you of the mind-numbing business of stopping and starting, as the E-Class's sensors keep an eye on the gap ahead.

So far, so familiar. But the E-Class has some new tricks in its catalogue. If it senses an accident is imminent, the car's Pre-Safe features leap to your aid. Depending on where it sees the crash coming from, the car will inflate the seat to push you away from the impact zone. Just before impact, it'll play some pink noise. This sound triggers your ears' defensive reflex, shielding your inner ear from sounds over 100dB, seconds before the potentially deafening noise of a crash.

THE E-CLASS USES
TECH TO STOP YOU
SQUEALING; THE
SKYLINE USES IT TO
MAKE YOU SCREAM

Of course, we didn't get see if this works, but it's nice to know it's there.

When you finally reach your destination, Alfred kindly uses its sensor array to park itself. You can sit comfortably in the driver seat while the car completes the manoeuvre, or jump out, fire up Mercedes Benz's Parking Pilot system on the app and watch the look on people's faces as the

car parks itself. All you have to do is keep an eye on your surroundings and a finger on your phone's touchscreen to keep the car moving.

CALL ME GODZILLA

While the E-Class uses tech to stop you squealing, Nissan's 2017 Skyline GT-R Prestige, affectionately dubbed 'Godzilla', uses tech to make you scream. Each of the wheels is watched by a CPU that reads the connection between the tyre and the road, delivering more or less power where needed to provide traction. Pair this with a new gearbox that changes gears faster than you can, and you get a car that approximates what it's like to be fired out of a catapult.

Outside of Tesla Model S 90D, the only other cars that can manage this kind of acceleration will need you take a mortgage out to even look at. It's a feat that's been achieved through sheer attention to detail. Each engine is hand-assembled by one of four 'takumi' - master craftsmen certified to build GT-R engines. This might not sound high-tech, but these engineers work in the margins of microns (one millionth of a metre). They've even designed the car to minimise bad road noise while pumping in good engine noise through the speakers to make it feel faster.

Obviously, to actually get your money's worth out of a GT-R you'll need to head to a track. With a Nismo edition, the sat-nav will pick up your location and switch your display to a map of the track, complete with your sector times and telemetry. You can record this data and, back at home, plug it into your PlayStation 3 to virtually race yourself on *Gran Turismo 6*, just like F1 drivers do.

Crucially, on the track, all this technology metaphorically falls away, giving you a drive that's friendly and scary all at once.





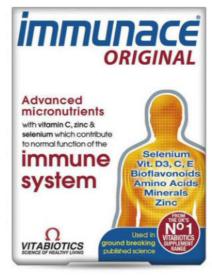




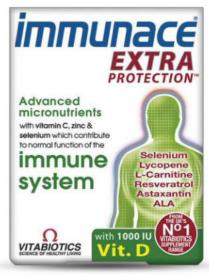
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MESSAGE OF THE MONTH

Monster mash

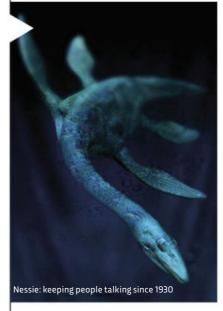
Darren Naish's article on the Loch Ness Monster (September) slightly garbles the history with regard to King Kong. The first modern report was in 1930. There was then a gap until April 1933, with nine encounters reported prior to the Spicer encounter in the summer. That the origins of Nessie lie with the release of King Kong is an appealing hypothesis but is probably overstated. The first 1933 encounter is on 28 April, post-dating the London launch of King Kong on 17 April. Highlanders would have seen little of the film until its opening in Inverness on 16 October, so it's hard to imagine it influencing the local witnesses who saw Nessie between May and July 1933.

The Spicer account is the first to mention the long neck of the Loch Ness Monster and the Spicers (visitors from southern England) may well have seen King Kong prior to their encounter. I suspect King Kong may have had influence on the UK-wide coverage of the monster in autumn 1933 and even initiated the idea of a long-necked Nessie, but King Kong fever doesn't explain the solely Scottish neckless monster of the early summer of 1933.

Charles Paxton, via email

The idea that the Spicers might have been influenced by creatures seen in King Kong is an interesting hypothesis long promoted by several veteran researchers, but it has always been just that: a hypothesis. Indeed, the King Kong link is not the only reason for considering the sighting problematic: as discussed in my article, there are reasons for thinking that their sighting can be explained in other ways (namely, by an encounter with deer), and in future I will be focusing on those aspects of the explanation alone. - Dr Darren Naish, University of Southampton

WRITE IN AND WIN! The writer of next issue's Message Of The Month wins a set of **Urbanista Seattle** headphones, worth £49. The headphones have crisp sound and impressive bass, while their memory foam ear cups mean you can listen to your music in comfort. uk.urbanista.com



Fruity idea

As you say in your October article on interstellar flight, the ultimate fuel, as used by Captain James Kirk of USS Enterprise, is

antimatter. Therefore, all we need to run such a ship is bananas!

Bananas are rich in potassium, having several tens of micrograms in each one of them, including about 0.01 per cent being potassium-40.

Potassium-40 decays by producing positrons. These positrons are in fact positive electrons, which is the fuel we need, viz antimatter! As a bonus,

the waste products of this gourmet fuel are biodegradable! Next stop, Proxima b?

Anthony Fenwick-Wilson, Shropshire

l feel obliged to say: what a load of bananas. - Ed

Spin me right round

I was disappointed that 'centrifugal' force was featured in an answer to a question in the September issue. In my opinion, the answer is an example of bad physics. It should mention that a centripetal force is provided by the gravitational pull of the Earth. The 'fly off' condition occurs when the centripetal acceleration exceeds the local value of acceleration due to gravity. Graham Smith, via email

The correct explanation does not require 'centripetal force'. Centripetal force is relevant only in the reference frame of an observer witnessing Earth's rotation from outside. In the rotating reference frame (of humans stuck to the surface of Earth).

> the motion appears to be linear so that we often add an

> > 'imaginary' force, called 'centrifugal force', which makes the net force in the radial direction zero. This imaginary force (more correctly called an 'inertial force') is added so that Newton's laws remain valid in the

accelerated (rotating)

reference frame. It is common to assume centrifugal force is somehow 'wrong' but in fact it is just as real and valid as centripetal force.

- Dr Alastair Gunn, Jodrell Bank Centre for Astrophysics

We need more

bananas, Scotty!"

Armageddon out of here

I loved last month's article about the end of the Universe by Brian Clegg. The Big Freeze scenario got me thinking about the arrow of time. If the Universe becomes 100 per cent uniform, will time stand still, as the present and the future become identical?

Alan Griffin, via email

◆ That's an interesting one. If the Universe were 100 per cent uniform and unchanging, you can argue whether there's no time, or time is just meaningless. In practice, the uncertainty principle means that there could still be short-term fluctuations in energy, allowing particles to briefly pop into existence, so there would probably still be something to measure time by, but no one there to measure it.

- Brian Clegg, science writer

In space, no one can hear you scream...

Congratulations on celebrating your 300th 'mensiversary' with another brilliant issue! *BBC Focus*'s arrival

in our household is always eagerly awaited. With Halloween just around the corner, I was slightly disturbed to notice at least six distinct skulls in Hubble's picture of NGC 2440! Presumably you didn't rotate NASA's original through 90 degrees just to facilitate their materialisation? I take the whole thing as irrefutable proof of the paranormal...

Adam Douglas, County Durham

We can only see two... how many can you spot, readers? – Ed



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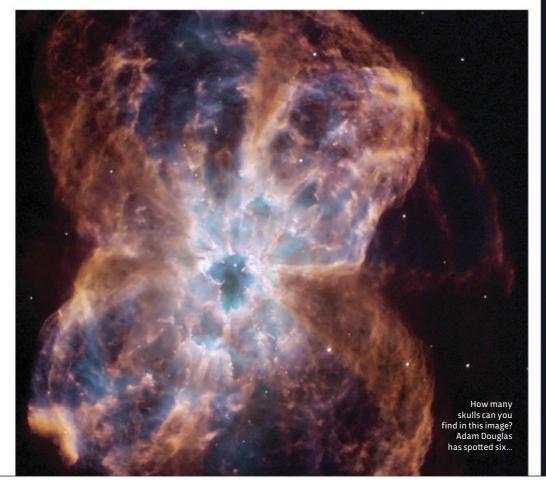


Special issue



THE THEORY OF (nearly) EVERYTHING

The latest special edition from the BBC Focus team takes you on a whirlwind tour of the biggest questions in science, from the Big Bang to the end of the Universe and everything in-between.





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THE RISE OF THE

CONSCIOUS MACHINES

As Als around the world start to surpass our own intellect, we ask how human should we make machines?

Words: George Zarkadakis

В

ack in the summer of 1956, the fathers of artificial intelligence (AI) gathered at Dartmouth College, New Hampshire, to christen the new science and set its goals. Their concept of 'human intelligence' was quite

narrow and specific. Computers would do what a rational, educated and mature man – for he was a man, and not a woman, that the fathers had in mind – did. He would use his knowledge and logic to solve complex problems. It was a goal that went beyond the purely numerical processing that computers were used for at that time.

The new science of artificial intelligence required a different computer that was capable of creating, •



What if we could reproduce the whole human brain, with all of its intricate wiring, in an electronic computer?

• storing and accessing knowledge, applying logical rules to facts and data, asking questions, concluding new facts, making decisions, and providing explanations for its reasoning and actions. Years before, the English mathematician Alan Turing had imagined an intelligent machine as one that would converse in our language and convince us of its human-ness. Nevertheless, the foundational machine intelligence aspirations had nothing to do with human feelings, morals, or consciousness. Although language understanding was included in the goals of early AI, the intention was not to replicate the human mind in a machine, but only mimic certain practical aspects of it. Besides, in the late 1950s our knowledge about the brain and mind was still in its infancy.

And yet, the temptation to think big was evident from the start. Already since 1943, pioneering neuroscientist Warren McCulloch and logician Walter Pitts had demonstrated the similarities between electronics and neurons. What if we could reproduce the whole human



brain, with all of its intricate wiring, in an electronic computer? What if instead of describing to the computer how to think, we let it think by itself, and consequently evolve a 'mind' of its own? What if we made AI more human?

Then in 1956, the same year as the Dartmouth College Conference, US psychologist Frank Rosenblatt invented the 'perceptron', an algorithm that ran on specific neuron-mimicking hardware and was capable of learning similarly to a neural network: by strengthening or weakening the connections between neighbouring, interconnected neurons. The perceptron was the ancestor of artificial neural networks and deep learning, or what we today – 60 years later – understand as the big idea behind 'artificial intelligence'.

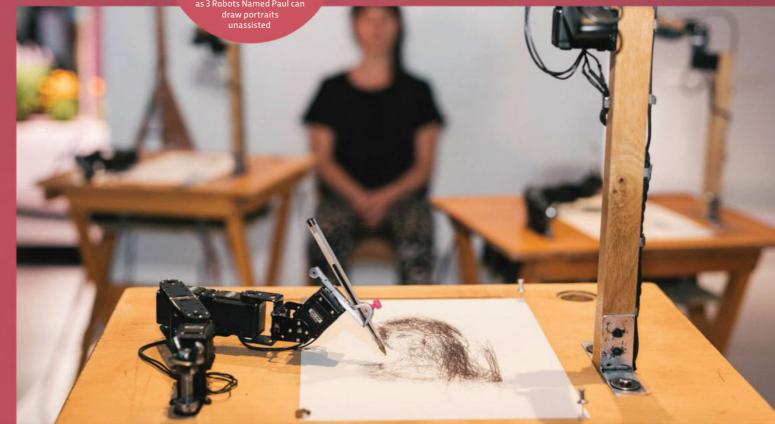
THINKING LIKE A HUMAN

The initial logical approach to AI produced some interesting results over the years, but ultimately ran into a dead end. Rosenblatt's pioneering invention provided an alternative approach, one

that enabled computers to go beyond logic, and venture into solving a really hard problem: perception. His work was almost forgotten for a while, but was resurrected by a new generation of brilliant scientists in the 1990s. With the cost of hardware capable of parallel processing dropping, it became possible to create algorithms that emulated the human brain. It was a technological breakthrough that redefined artificial intelligence and its goals.

We now live in a time when intelligent machines are breaking records nearly every day. As billions of dollars of investment pour into AI research, machines are becoming smarter. The key to their accelerating smartness is their ability to learn. An artificial neural network – just like the 'natural' ones inside our brains - can learn to recognise facts by processing data through internal interconnections. For example, it can process the pixels of an image and recognise the face of a human, or an animal, or an object. And once artificial intelligence learns how to infer facts from data, it can do so





THE RISE OF ARTIFICIAL INTELLIGENCE



We can make neurons from silicon. Neuroscientist Warren McCulloch and logician Walter Pitts (pictured) demonstrate that a neuron can be emulated using electronics, thus paving the way for artificial neuron networks.





• again and again, much faster than our brains. Such machines need a lot of data in order to learn, and often a human trainer to supervise the learning. But machines can also learn by themselves, through a process called 'reinforcement learning'. That was how AlphaGo, the algorithm developed by UK-based company DeepMind, was able to beat the world champion of Go. In a game famous for its complexity, the machine became an honorary 9-dan black belt master by playing against instances of itself.

AlphaGo was a watershed in the evolution of artificial intelligence because it offered a glimpse of the

ultimate goal: the creation of general, human-like intelligence. To win at a complex game such as Go you need to think creatively, and use 'intuition'. This means being able to draw from previous learnings and apply them effectively to new and unexpected problems. But computers are not there yet. They are still in the recognition intelligence phase: they can infer facts from data by recognising images, sounds, or human language, and make predictions based on their understanding of the data.

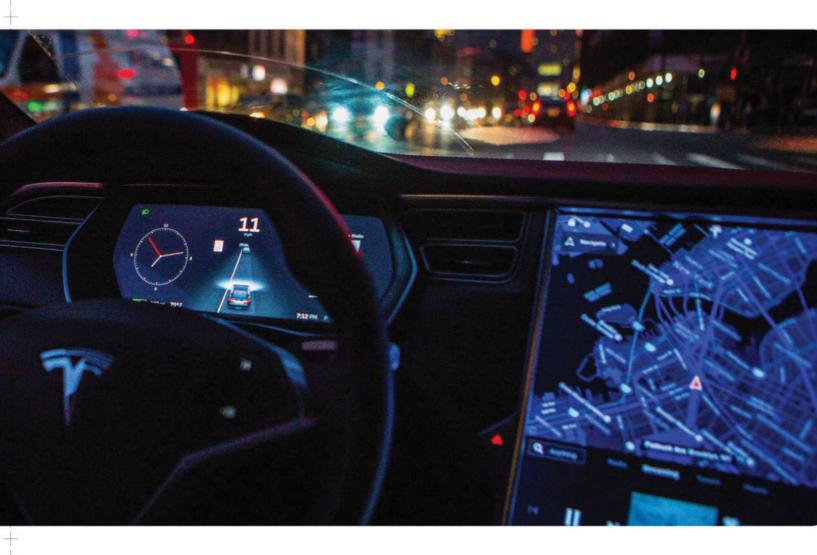
The next step towards becoming more 'human' requires machines to use their understanding in order to make real-

The next phase in AI evolution is for machines to enter the problematic areas of human morality

How to identify a thinking machine. In a groundbreaking paper, Alan Turing describes the imitation game, or how to tell if a machine has reached human-level intelligence by having a conversation with it



Al is given its name. The Dartmouth College Conference is considered the founding event for artificial intelligence. John McCarthy, one of the organisers (pictured), is attributed with giving the discipline its moniker.



time decisions and act autonomously. For example, it is not enough for a driverless car to recognise that a collection of pixels is a white van in front of it that is slowing down quickly. It must also reason that it needs to take evasive action. In doing so, it may have to decide between life and death. In other words, the next phase in AI evolution is for machines to enter the problematic areas of human morality.

THE MORAL IMPERATIVE FOR AI

The justification to make artificial intelligence more human-like is overwhelming. We value 'intelligence'

as the cornerstone of our evolution. This value is deeply embedded in every human culture. What made our species survive against better-equipped predators was our ability to learn, invent and adapt. AI will turbocharge human intelligence and creativity. The economic reasons for pursuing eversmarter machines are also profound.

Although artificial intelligence will disrupt many professions, such as manufacturing and retail, there is no other technology that has such potential to secure continuous economic growth and prosperity for future generations. For science, the advent of machines that

can process vast amounts of data and discover new knowledge could not have come at a better time.

Every scientific discipline is benefiting from AI to manage the data deluge. Physicists use it to research the fundamental laws of nature, biologists to discover new drugs for curing disease, doctors to provide better diagnoses and therapies. Pursuing the further development of machine intelligence for cultural, economic, and scientific reasons makes perfect sense. But as our machines become more human, and as more applications start to embed some artificial intelligence, •

1973

The Lighthill Report triggers Al winter. The report, which is named after the British mathematician John Lighthill, is compiled by the UK's Science Research Council. The report urges the UK government to stop funding Al research, stating that "in no part of the field have discoveries made so far produced the major impact that was then promised".



The rise and fall of 5th Generation Computing. A grand plan is made by the Japanese government to develop human-level thinking machines using 'massively parallel computing'. The plan was abandoned eight years later in 1990.



WHAT WE CAN LEARN FROM AI IN THE MOVIES

ROY BATTY – BLADE RUNNER

Artificial, conscious machines will be just like us. They'll react to social rejection, strive for survival, defend their own, and seek to extend their lifespans by any means.

HAL - 2001: A SPACE ODYSSEY

Never build an AI that does not have an off switch, especially when the AI is in full control of a spacecraft. HAL was very bad engineering. Health and safety for space missions take notice!

DAVID – AI

David is a robot child designed to feel love. The film then spends the next two hours throwing every hardship that life can muster at him and his Al toy, Teddy. As Als become conscious, we need to recognise their emotions and rights too.

AVA – EX MACHINA

An eccentric billionaire, Nathan, designs Ava to pass the Turing test. But her abilities are so exceptional that not only does she fool Caleb, a programmer who is testing her consciousness, but she even outsmarts Nathan – a thinly-veiled Mark Zuckerberg clone. We should be aware that the Turing test isn't the last word in Al.

SAMANTHA - HER

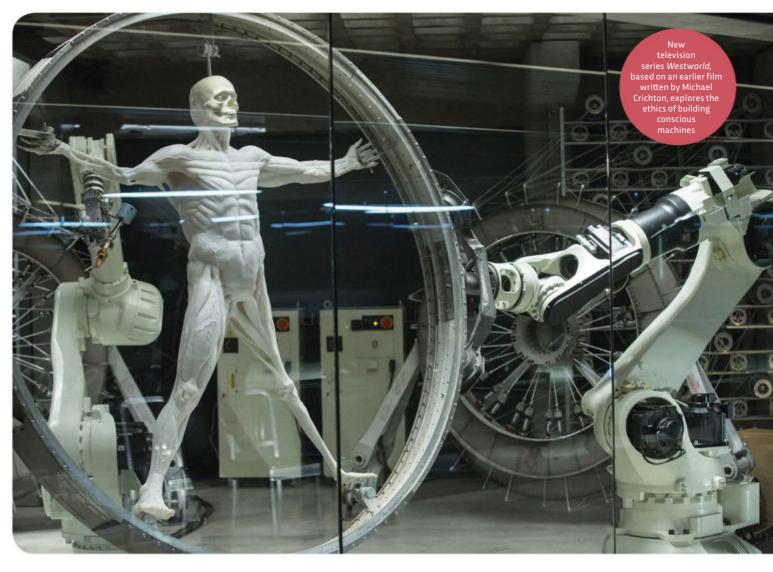
Once Als become human-like, love and sex will also enter the equation of our relationship with them. But how can you have sex with lines of code? The scene of Samantha's incarnation in a human avatar is virtual reality seeking to become actual reality – mindboggling!



166**7**

Chess player gets beaten by Al. IBM's supercomputer Deep Blue beats world chess champion Garry Kasparov in a high-profile match. Kasparov becomes frustrated and walks away when the computer inexplicably moves a rook. It has since been claimed Deep Blue's move was probably down to a bug.





• a fundamental problem is beginning to emerge.

Emulating the human brain with artificial neural networks means that computers are mysterious and opaque. This is the so-called 'black box problem' of AI. In the brain and the machine, information is diffused in the network. When we retrieve a phone number from memory, we do not access a part of the brain where the number is somehow etched in flesh. Instead, each number is dispersed along multiple synapses that connect various neurons, at various

levels of organisation. We do not really 'know' what we know, or how we know it. It is only because we possess consciousness that we are able to rationalise in retrospect, and thus 'explain' our intuitions and ideas. As US neuroscientist David Eagleman has shown, most of what we become aware of has already happened in the brain at a non-conscious level. For humans, this has historically not been a problem, because we have assumed in our moral and legal systems that each of us is personally responsible for our thoughts

and actions — at least when the chemistry of our brains is within socially-accepted ranges of 'normality'. Nevertheless, for a non-conscious intelligent machine the 'black box problem' suggests that, although predictions and recommendations made by the machine may be accurate and useful, the machine will be incapable of explaining its reasoning. Imagine a driverless car taking a life and death decision, crashing, and killing a number of humans. With present day technology it is •

Video games spur machine learning. Nvidia releases the GeForce256 graphic processing unit (GPU) for video gaming. It also provides a cost-effective way to experiment with parallel processing. Deep learning pioneers such as Yann LeCun start using GPUs to develop advanced machine-learning algorithms.

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Machines get smarter. IBM
Watson beats the two
Jeopardy! champions and wins
the \$1m prize. The computer
was so good that engineers
had to slow it down lest it
spooked the contestants.

• impossible to decode why the machine took the decision that it did.

The black box problem is intensified when the data that a machine uses to learn has intrinsic biases, which could lead to biased conclusions or unsocial behaviour. In March 2016, for example, Microsoft released a bot on Twitter with the ability to learn human language by analysing live tweets. In less than 24 hours it had started tweeting racist and xenophobic rants. Scientists have been trying various approaches to solving the black box problem. In October 2016, DeepMind scientists published a paper in the journal Nature describing a 'differentiable neural computing machine' that combined a neural network with conventional external memory. Separating the processing from the data is a step towards ethically accountable intelligent machines. It makes it theoretically possible to code moral values that validate, or inhibit, the black box outcomes of neural networks. But this hybrid approach to developing safer artificial intelligence may not be enough in the future.

THE REAL MORAL DILEMMA

After a bumpy start and much disappointment over the years, humanity has hit upon a technology with the potential to reshape everything. The economic and cultural impetus for exploiting the furthest boundaries of machine intelligence suggests that we will ultimately arrive at general, humanlike intelligence, possibly in the next 10 to 20 years. Predictions may vary but if recent developments are a guide, we should expect general artificial intelligence sooner rather than later.

When this happens, we will have created machines capable of ingesting massive amounts of data and delivering superhuman insights and predictions. Ironically, and if the black box problem remains unsolved, we may then find ourselves in a position similar to the Ancient Greeks visiting the Oracle of Delphi and asking Apollo to predict their



With artificial intelligence we are creating new gods whose intellect will far surpass our own

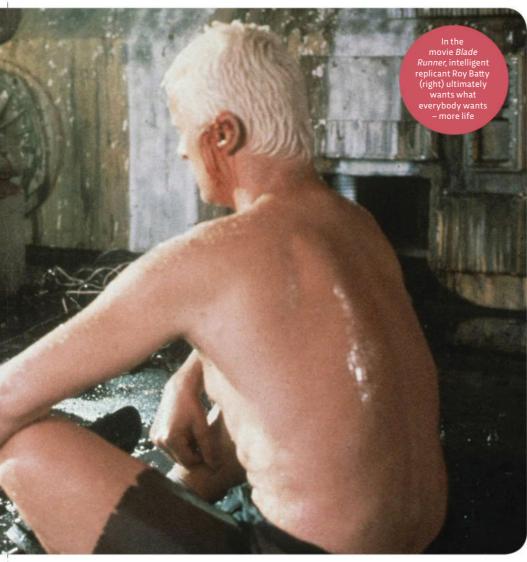
future. The language of the god was completely incomprehensible to humans so a human mediator – Pythia – was summoned to deliver cryptic utterances, which priests then interpreted in various, conflicting ways. With artificial intelligence we are creating new gods whose intellect will far surpass our own. Their reasoning will be beyond our understanding. We will thus face an intolerable dilemma. Should we trust these new silicon gods on blind faith? It is very unlikely that human-level

2016

And smarter. In March, AlphaGo – an algorithm developed by Google company DeepMind – beats Lee Sedol, the world champion of the complex game Go. Experts concede that they did not expect this to happen for another 10 years.

Human dies while driving a Tesla Model S on Autopilot. In May, 40-year-old Joshua Brown was killed when his car hit a large truck. Tesla told investigators that the crash-prevention system failed and the Autopilot was not at fault, in the midst of calls for the company to remove the feature from its cars.





artificial intelligence with no ability to explain its reasoning will be socially acceptable. This leaves us with only one choice: to develop artificial intelligence even further, and equip it with human characteristics such as emotional intelligence, empathy and consciousness. Indeed, that would be the only way to solve the problem of communication between intelligent machines and us. The machines of the future will have to intuitively pick up our emotions and adapt to our moods

and psychological profile. They will have to learn to tell how we feel, by analysing our voice and expressions, and drawing conclusions on the basis of the massive data they will have collected about us over the years. That is how they will be able to gain our trust and become part of human society.

Unlike our 'human' friends, these emotionally intelligent machines will know everything about us. We will not be able to hide anything from them. They will probably know much more about us than we would know about ourselves; and that's how they will be able to guide us in making better decisions and choices in our lives. To have 'someone' like that in one's life would be invaluable, and making artificial intelligence ever more human and empathetic would be welcomed.

Nevertheless, this dependency on such an intelligent machine poses a number of ethical questions. If we have a machine to always protect us from our errors, like a well-meaning and all-wise parent or partner, how will future humans learn from making mistakes, and therefore mature as individuals? Wouldn't an all-caring, all-seeing AI result in the infantilisation of people and culture? And what about AI achieving consciousness? Should we be pushing the limits of technology to make machine self-aware? Would it be wise to breathe life into a lifeless jumble of wires, cooling fans and chips? Mary Shelley's gothic masterpiece Frankenstein, and Ridley Scott's Blade Runner provide useful insights to anyone aspiring towards such a future.

The limits of making artificial intelligence more human must surely be set before such a goal is ever achieved. Self-awareness will make machines capable of setting their own goals, which may be somewhat different from our own. Given our increasing dependency upon them in the future, those self-aware machines may well decide to manipulate our trust to meet their goals. And the master, who created an equal, may thus end up a slave.

George Zarkadakis is an artificial intelligence expert and the author of *In Our Own Image: Will Artificial Intelligence Save Or Destroy Us?* (£12.99, Rider Books). He tweets from @zarkadakis.

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Find out more about artificial intelligence with a selection of articles on the BBC Future website at bbc.in/2e6zKzQ



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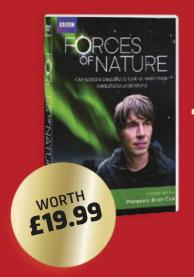
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Our planet's human population is booming, making the urban environment the fastest growing habitat on Earth. Animals living in or near cities have to cope with constant movement and change. Yet our bustling streets also offer rich bounties in the form of food, shelter and warmth.

For Planet Earth II, I spent almost four years making a film on urban wildlife. What excited me so much was exploring the surprising new ways in which animals are overcoming the challenges of living in human habitats, carving out a home in these alien worlds.

◄ Mumbai leopards

When we set out to film leopards in Mumbai, India, we were hoping to capture them hunting, but in the backs of our minds we were questioning whether we would even see one. Film crews have tried before and only captured glimpses of this highly elusive cat. For any large carnivore to survive in the urban jungle it has to keep to the shadows, and leopards are known for their stealth.

To give him the best chance of spotting a leopard, our cameraman Gordon Buchanan was equipped with a thermal camera, which he used to scan the horizon for warm-blooded animals out at night. This area of Mumbai does, in fact, have the highest concentration of leopards anywhere in the world. During the day, they sleep in a forested park. When night falls, they head into the streets to hunt for domesticated animals (such as dogs and pigs) that make up a large proportion of their prey.

With the thermal camera and a good deal of luck, Gordon was able to capture remarkable footage of urban leopards hunting. But what amazed him most was to see just how close to people they roamed.



▲ Hyenas in Harar

When I heard about spotted hyenas freely running through the streets of Harar, Ethiopia, I couldn't quite believe it. The story goes that over 400 years ago, when the city walls were being built, 'hyena gates' were incorporated... not big enough to allow in an opposing army, but just right for a hyena. Now, two hyena clans enter the city through these gates every single night in search of bones left out by the town butchers.

While walking down a narrow cobbled street on my first night in the old town, I held my breath as eight hyenas walked past me, brushing my leg. A few nights later I filmed the two dominant hyena clans fighting over access to the city. Over a hundred hyenas were battling around my feet, and somehow my fear had disappeared. The peaceful pact between humans and hyenas in this city was so evident that I didn't feel in danger.

I am told that inside the city walls the hyenas never attack people or livestock. But why are they welcomed here, when elsewhere on the planet they are vilified? It's because Harar's inhabitants believe that each time the hyenas cackle they are gobbling up a bad spirit in the street. It's a truly remarkable example of how humans and beasts can live alongside one another harmoniously.

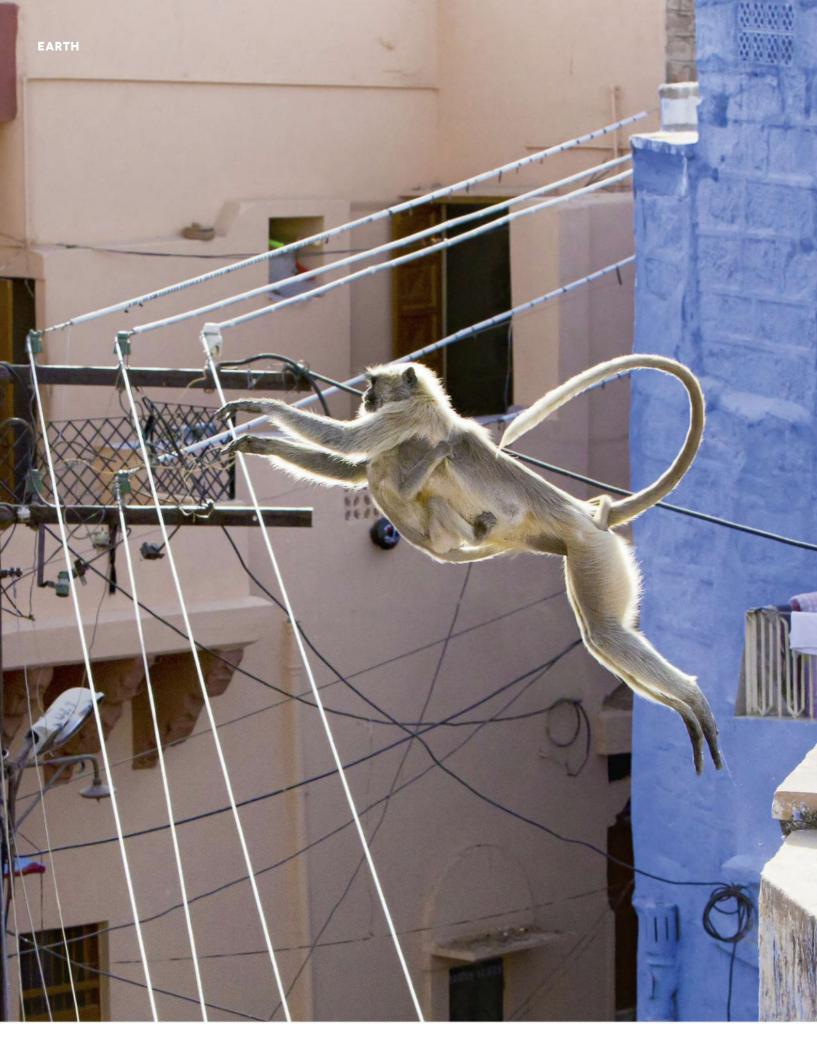
Bowerbird bling ▶

Filming great bowerbirds in Townsville, Australia, was a particularly enjoyable endeavour. These are highly intelligent birds, full of character and each with their own distinct aesthetic. For them, the city is a treasure chest of brightly coloured objects that they can collect and decorate their bowers with. Their hope is that all this bling will impress a female.

We first had to find our character. We were looking for an old male (they can live to 25 years old), as these tend to have the most impressive bowers. They also tend to be the biggest thieves! The birds prefer to steal from neighbouring bowers than search for their own objects within the city. Indeed, bower crime is higher in the urban environment than in the neighbouring countryside. Perhaps there are just too many alluring objects to acquire. These thieves are particularly keen on synthetic objects because they tend to hold their colour and do not perish in the sunshine.

It's amusing and fascinating watching the birds spend two hours every day meticulously rearranging the objects in their bower. But the real entertainment begins when a female arrives. Then, the bower entrance becomes the male's stage, and his dance can begin.





◄ Metropolitan monkeys

It was a thrilling moment photographing this female Hanuman langur leaping with her baby across a six-metre gap, four storeys high, in Jodhpur, India.

Each morning, we watched a group of 15 bachelor males pile in to the heart of the 'blue city' to challenge the resident alpha male for his territory. The alpha would often have to chase the bachelors for over a mile across the rooftops. The reason that this area is so highly contested is because it's perhaps one of the best langur territories in the world. Hindus associate these primates with the monkey god Hanuman, and revere them. In the temple gardens, they're given all the food they can eat. The alpha male has sole mating rights with the adult females in his troop and, because of their energy rich diet, they are more fertile than the Hanuman langurs found in neighbouring forests.

What struck me on this shoot was just how generous the Indian people are towards wildlife living in their cities. The reward for them is being surrounded by wonderful animals.

Crafty raccoons ▼

Raccoons are doing incredibly well in North American cities. They are well adapted to finding food in the concrete jungle, and by being active at night they avoid contact with humans. They can squeeze through small gaps, and have incredibly dextrous hands. They are also the perfect size for accessing rubbish bins or opening shed doors. If you're too big you are easily noticed, and that's why we see medium sized scavengers, such as raccoons and foxes, doing so well in our cities

For me, the most remarkable thing about urban raccoons is that they are better at solving problems than their country cousins. A recent study showed that they are willing to invest more time in trying different techniques to access food, perhaps because the rewards in the city can be so rich. The team saw this on the shoot when they observed a mother raccoon come back for three nights in a row to try to get into a bird feeder filled with nuts. It was only on the third night that she succeeded, but it was worth it!



EARTH







▲ Bird-eating fish

It was a huge surprise to hear the story of a fish catching and eating a bird – it's usually the other way round! The wels catfish tends to feed on invertebrates and smaller fish, but in one place in Albi, in the south of France, it has developed a taste for pigeon.

Next to a 1,000-year-old bridge in this city is a 'No fishing' sign. For this reason, catfish are found in enormous numbers, and they grow up to 2.4 metres in length. By the end of summer, there are not many fish for left for them to eat. So, in the last 15 years, some of them have turned their attention to catching pigeons instead.

As the pigeons bathe, oil from their feathers starts to flow downstream, and the catfish detect the smell. It's an eerie sight seeing this river monster swim towards a group of birds splashing in the shallows. When a fish strikes, you can hear a loud sucking noise – rather like something disappearing up the vacuum cleaner – as it slurps the bird into its mouth.

Opportunist geckos ▶

The invention of the incandescent light bulb just 140 years ago changed our night skies forever, and nowhere more so than in cities. For many animals, artificial light creates confusion. Moths have evolved to navigate by flying at a constant angle relative to a distant light source: the Moon. That's why they're often found flying round and round street lights. But one animal is taking full advantage of these confused insects.

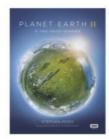
This tokay gecko was photographed in Hong Kong. Hong Kong has a great deal of light pollution, with one of the brightest night skies in the world. As the tokay gecko is a nocturnal lizard, you wouldn't imagine that its eyes could cope with such bright light, but their vertical slit pupils allow them to see in a far greater range of light conditions we can. The tiny slit only lets in a small amount of light when under a bright bulb, but opens wide in the dark.

The other feature that makes tokay geckos so well adapted to the urban environment is their phenomenal grip. Each foot is lined with half a million microscopic hairs, so tiny that they form a molecular bond with the surface, almost like atomic scale Velcro. Having evolved to walk on wet leaves in the rainforest, their feet stick well to metal and glass, making this lamp post an ideal place to dine!

DISCOVER MORE

You can see more breathtaking images from the series in the accompanying book, *Planet Earth II: A New World Revealed*, available now (£25, BBC Books).

For more fascinating features about the natural world, pick up a copy of our sister title *BBC Wildlife*, available in good newsagents.



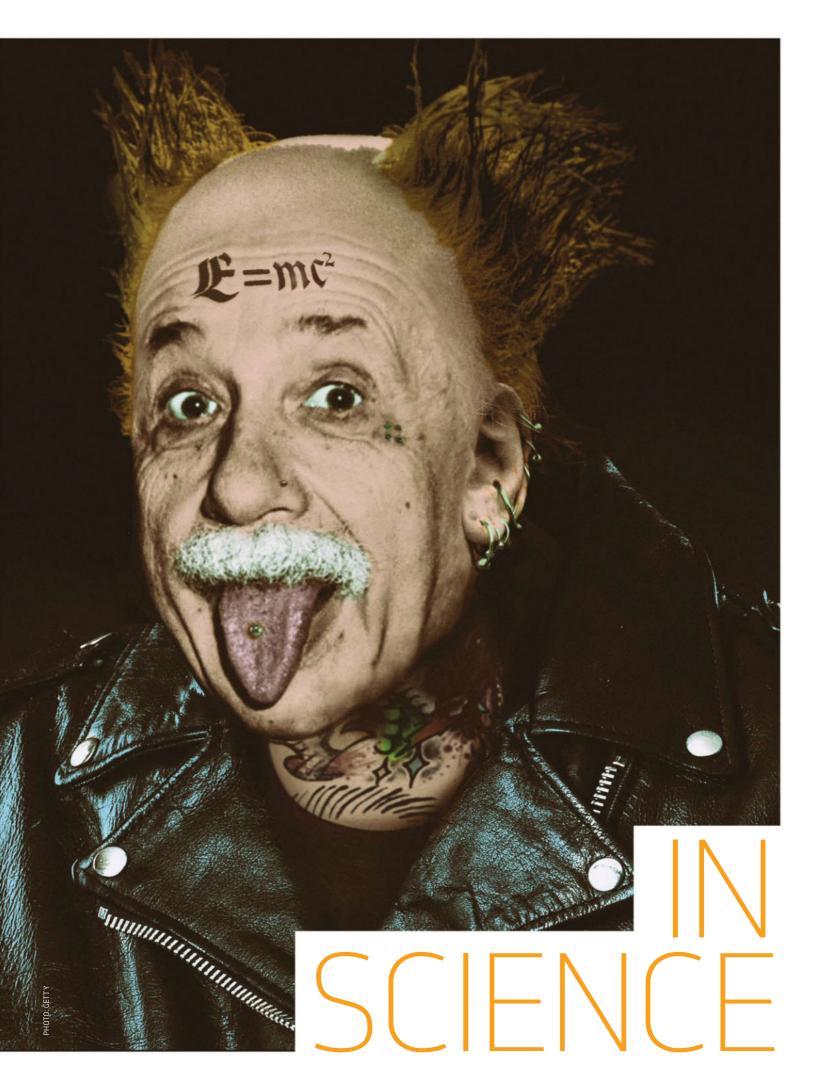




STRANGEST IDEAS

As Albert Einstein once said, "imagination is more important than knowledge". So with that in mind, here are some of the most radical theories in science, from anti-ageing humans to the Earth's second sun

WORDS: DUNCAN GEERE





Psychedelic drugs may help treat mental illnesses

It's no secret that drug policy is confusing. At times, it can seem that there is little scientific rigour involved in the regulation of substances (for up-to-date, confidential advice and information on drugs, visit talktofrank.com). This state of affairs is changing slowly, however, as researchers discover previously unknown, positive effects in some of the most villainised drugs.

Of particular interest is the use of psychedelic drugs in treating mental illness. At Imperial College, scientists have been mapping the effects of LSD on the brain, showing that it can be used to develop therapeutic approaches for breaking patterns of negative thought and treating depression.

Elsewhere, psilocybin, the active ingredient in magic mushrooms, has been found to be effective in alleviating anxiety and depression among cancer patients for as long as six months after a single dose.

And in tests on mice, a chemical by-product created when the body breaks down the ketamine has reversed depression-like behaviours without triggering any of the dissociative or addictive side effects normally connected with the drug.

All this adds up to a potential renaissance when it comes to understanding how these drugs affect the human body. Perhaps soon, a visit to the doctor may mean coming away clutching a prescription for something that would currently see you locked up.





The blood of the young can slow down the ageing process, accelerate healing and even treat degenerative brain disorders. That's not the plot of a sci-fi novel, it's the result of new research by degeneration expert Dr Tony Wyss-Coray at Stanford University. Though to be clear, he's only experimented on mice so far. "We discovered that circulatory factors in the blood of young mice are sufficient to slow or reverse behavioural deficits and other signs of brain ageing in old mice," he says.

In other words, old mice that share a blood supply with young mice are rejuvenated: their brains, muscles, pancreases, livers and hearts start behaving like those of a younger mouse.

The discovery originally came about when Wyss-Coray was trying to find a protein

biomarker for Alzheimer's disease. "We noticed that the biggest changes in dozens of measured proteins occurred with ageing rather than with disease," he says.

His colleague Dr Tom Rando had previously shown that young blood can rejuvenate old muscle stem cells, so Wyss-Coray decided to see if the brain would benefit from the same process. It did. In maze testing, older mice that had been injected with plasma from young mice performed as if they were half their age. When their brain tissue was examined, the team discovered that the exposure to young blood had strengthened connections between neurons that normally weaken with age.

But can the results be recreated in humans? "We are planning to treat 18 patients with mild

to moderate Alzheimer's disease and hope to finish recruitment this year," says Wyss-Coray. "Once the trial concludes we will analyse the data. There are no results before then."

Elsewhere, a worrying market has begun to emerge in blood plasma. "I strongly believe in clinical trials and think there should be no treatments done without a positive phase 3 clinical trial result," he adds. "Until then, I feel nobody should really pay for plasma infusions."

But even if it does work, there are probably limits to the effect. "Biological systems are too complex to be maintained and regenerated indefinitely," says Wyss-Coray. "Even if our findings can be translated to humans, I think we will only have limited effect on some, but not all, aspects of ageing."

Five of the most bizarre science experiments in history



JOHN PAUL STAPP AND FLIGHT TESTING When jets were

developed after ions were raised

WWII, questions were raised over what kind of acceleration the human body could safely handle. Colonel John Paul Stapp from the US Air Force volunteered for a series of tests that subjected him to g forces of up to 45g. He survived the experiments with no lasting injuries and died at the grand old age of 89 in 1999.



JOSÉ DELGADO AND HIS BULL BRAIN CONTROL In 1963, Yale researcher Dr

José Delgado stepped into a bullring in Cordoba, Spain.
A huge, angry bull charged straight at him. But Delgado calmly pressed a button on a remote control, which sent a signal to an electrode he'd implanted in the bull's brain the previous day. The animal huffed a few times and walked calmly away, leaving Delgado unharmed.



STANLEY MILGRAM EXPERIMENTS In the wake of the war crimes

trials of Nazi leaders, a public debate emerged over whether 'just following orders' was a valid legal defence. Yale psychologist Dr Stanley Milgram performed an experiment to find out, using electric shocks to prove that people will obey even the most awful orders when they are delivered by figures in authority.



STUBBINS FFIRTH AND YELLOW FEVER In 1804, a trainee doctor named

Stubbins Ffirth went to extraordinary lengths to prove that yellow fever wasn't contagious. He smeared vomit from infected patients into cuts on his arms, poured it into his eyes, fried it and inhaled the fumes and drank it. He didn't contract the disease, but it was later found that the samples came from patients who were no longer contagious.



MARGARET HOWE AND PETER THE DOLPHIN In the 1960s, NASA funded

research into communicating with dolphins, hoping that the principles would allow us to talk to aliens. For 10 weeks, Margaret Howe lived with a dolphin named Peter in a lab flooded with water. Over time, Peter became disruptive, showing sexual attraction to Howe. She relieved his urges manually so the experiments could continue

Living and thinking beings can spring into existence from nowhere

According to quantum mechanics, space is anything but empty. It is full of particles constantly flitting in and out of existence thanks to quantum fluctuations in energy. In principle, these fluctuations could give rise to collections of particles such as a hydrogen atom, a microwave oven, or even a living, thinking brain. The catch? The Universe would have to be infinitely big and exist for an infinite period of time for this to happen. Dubbed 'Boltzmann brains' after the 19th-Century Austrian physicist Ludwig Boltzmann, the idea goes like this: though the chance of such an event occurring is minute, it isn't zero. Therefore, it is theoretically possible that, in an infinitely big universe, over an infinite period of time, such a thing could occur. There could be Boltzmann brains on planets, they could be floating in space. They could be anywhere.

According to some calculations, it is more likely that there are Boltzmann brains existing in the Universe than beings that evolved gradually though natural selection. The trouble is nobody has seen one. For some, the theory is something of an embarrassment, and debate still rages among cosmologists of how exactly to rid physics of this so-called 'Boltzmann brain problem' once and for all.







Memories can be passed down in your genes

It's pretty clear that organisms pass some form of knowledge down in their genes. Newly hatched sea turtles will automatically move towards the sea, while baby kangaroos climb into their mother's pouch when born.

The term we use for such behaviours is 'instinct' but some researchers believe it may be possible to transfer more than just instinct through genetics. They propose that knowledge, including learnt abilities and the rules that govern them, can also be embedded in our genetic code.

"There is ample room on DNA to store phenomenal amounts of information," says Dr Darold Treffert, a psychiatrist who specialises in the study of savants. "The entire Library of Congress, for example, could be recorded on a speck of DNA."

Savants are people with developmental disorders such as autism, who also demonstrate remarkable capabilities in certain areas. They may be a musical genius, an exceptional artist, have a photographic memory or be able to perform complex maths calculations in their head.

Treffert says that the ability of savants to display prodigious skills without learning them is proof of 'genetic memory', the ability to pass memories down in the genes. "We do not start with a blank disk," he says. "Beginning life with much inherited software applies to us all."

The idea isn't new. Eminent Swiss psychiatrist Carl Jung proposed the idea of a 'cosmic consciousness' that some people could tap into. The concept of reincarnation deals with similar principles.

These ideas tend to be rejected outright by modern mainstream thought, in favour of a 'nurture' approach to how we acquire knowledge. But there is some experimental evidence to the contrary. Scientists at Emory University trained mice to fear the scent of cherry blossom by giving them a small electric shock every time they smelt it. After several repetitions, the mice began to cower whenever they smelt the scent, regardless of whether they were shocked or not. This may be exactly what you would expect, but the team also found that two subsequent generations of rodents whose parents had been trained to fear a smell similar to cherry blossom would avoid the scent, despite never having experienced the associated electric shock.

Treffert believes that his research is key to understanding how this process works. "I think savants, both congenital and acquired, are irrefutable evidence for the 'nature' side of the argument," he says. "I am just reporting what I have observed in so many savants now, and I'm searching for an explanation. Genetic memory makes the most sense to me."

The first human to live to 1,000 is alive now

Around the globe, about two-thirds of all deaths are from age-related causes. In industrialised countries, that figure rises to 90 per cent. Forget terrorism, malnutrition, war and malaria – when you look at the stats, the world's biggest killer is old age.

Over the millennia we've figured out a lot of ways to live longer, from tool-making and control of fire, through to writing, agriculture, trade, the scientific method, democracy and so on. Today, new medical technology is extending our lifespans at a rate of about two years a decade. But what if we could increase that rate beyond the rate at which we age?

That's the question that SENS Research Foundation, founded in 2009 by expert in ageing Aubrey de Grey, is trying to answer. SENS says there are seven major types of 'damage' that occur in the human body and result in ageing: cell loss; mutations in mitochondria (a cell's 'energy factory'); junk proteins accumulating inside cells; junk proteins accumulating outside of cells; cancer-causing mutations in nuclear DNA; useless or harmful cells that don't die; and excess cross-linking proteins weakening bonds between cells within a tissue. For each of these areas, SENS has developed at least one proposed therapy and is now working towards starting human trials.

About a decade ago, de Grey made the grand prediction that many people alive today are going to live to 1,000 or more. He says he's still confident in that. "The science has proceeded very much along the path I had expected – not as rapidly as I'd hoped, but that's only because it's been harder than I'd hoped to attract the necessary funding," he says.

However, he admits that there aren't any low-hanging fruits in terms of achieving substantial life expectancy increases. "Multiple different types of damage can kill us by accumulating to levels that the body can't tolerate, and they require multiple different interventions to repair," de Grey explains. In the context of ever-more-sophisticated medicine, de Grey believes

Medical that there's no upper limit to how long a technology is human can live. "It's like vintage cars," he says. "Cars that only receive the level of extending our maintenance that the law requires have a lifespans at very predictable upper limit to lifespan. But throw in a dollop of additional maintenance two years a effort, and lo and behold, indefinite longevity. I don't think anyone is saying decade that cars that are currently 100 years old will definitely not make it to 200."

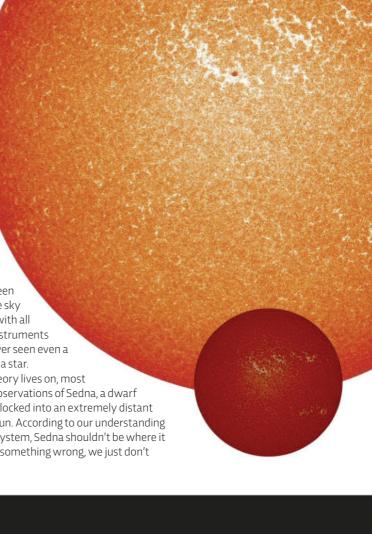
The Sun has a hidden twin The Universe is filled with binary star systems in which planets rotate around more than one star at the same time. But the Solar System just has one star, the Sun, right? Well, perhaps not if the 'Nemesis theory' is correct. The theory goes something like this: over the last 250 million years, Earth has seen mass extinctions every 26 million years or so. The idea is that these extinctions were caused by the catastrophic impact of comets sent hurtling into the inner Solar System by a small second star called Nemesis - the Sun's twin star. We've never

spotted Nemesis because it's very dim and small compared to the Sun, and it's moving very slowly from our perspective.

Large parts of the theory are open to dispute. The scientific consensus is that Earth's mass extinctions don't in fact occur on a predictable cycle, and there's no evidence for periodic

impacts in Earth's crater record. Oh, and there's also the fact that we've been searching the sky for decades with all manner of instruments and have never seen even a whiff of such a star.

But the theory lives on, most recently in observations of Sedna, a dwarf planet that's locked into an extremely distant orbit of the Sun. According to our understanding of the Solar System, Sedna shouldn't be where it is. We've got something wrong, we just don't know what.



Human intelligence emerged as a freak genetic mutation



Two hundred thousand years ago, human brains were substantially smaller than they are today. They'd been growing slowly for about three million years or so, but then abruptly there was a dramatic increase of about 30 per cent or so.

So what happened? Prof Colin Blakemore, a neurobiologist from Oxford University, believes that it's all down to an individual named 'Mitochondrial Eve' who lived about 200,000 years ago.

His theory is that a dramatic and spontaneous mutation in the brain of Mitochondrial Eve, or one of her relatives, substantially boosted our brainpower. It brought us to a level that allowed us to come up with solutions to crises like droughts and climatic changes that would otherwise have killed us off. From there, natural selection did its work.

The upshot of this theory is that *Homo sapiens* is something of a genetic accident. It's probably no surprise to learn that not everyone is on board with this idea, with most researchers believing that our intellectual abilities were gained through gradual evolution. But if Blakemore is correct, then perhaps we've only seen the start of what the human brain is capable.

The Universe is created by life, not the other way around



Physicists argue that their field is the most fundamental science. After all, every other science – biology, engineering, chemistry and so on – depends on the substances, energies and interactions of physics.

But Robert Lanza, a US doctor and eminent scientist, believes this is upside-down, and that biology is the central driving science in the Universe. He calls his theory 'biocentrism'.

Lanza first set out his ideas in a 2007 article that appeared in *The American Scholar*, and later expanded them in a 2009 book titled *Biocentrism: How Life And Consciousness Are The Keys To Understanding The True Nature Of The Universe.* In both works, he argues that consciousness creates the Universe, not the other way around. "Biocentrism is a new theory of everything," he says. "In this view, life and consciousness are central to any true understanding of the Universe."

Take the classic double-slit experiment, one of the mysteries in quantum mechanics. If you fire a beam of electrons at two parallel slits onto a screen, the electrons travelling through one slit interact with those travelling through the other to produce an interference pattern. However, the pattern is still produced even if the electrons are fired through one at a time. They seemingly interact with themselves. But that's not all. If we observe which slit each particle travels through, then the pattern isn't formed. The particles no longer appear to interact with one another. It's like they 'know' they're being watched. Physicists are yet to solve this problem, but Lanza thinks he has the answer.

"How can a particle change its behaviour depending on whether you watch it or not? The answer is simple – reality is a process that involves our consciousness," he says.

The same logic holds for entangled particles: the phenomenon that the specific quantum states of particles are seen to remain connected regardless of the distance between them. "How can a pair of particles possibly be instantaneously connected on opposite sides of the Galaxy? Because they're not – space and time are simply tools of our mind," Lanza says.

Reception to these ideas has been mixed. Some have questioned whether biocentrism can ever generate testable predictions, while others have argued that it is more of a philosophical than a scientific theory.

Lanza disagrees. "They are incorrect," he says. "Even the entanglement of living beings might soon be scientifically testable."

PHOTO: NASA/HUBBLE



Without action now the Grauer's gorilla could be gone forever – cut the coupon or go to www.supportgorillas.org to help protect the remaining 3,800 gorillas.

Consumed by conflict and caught in the grip of a severe conservation crisis, the Grauer's gorilla – the world's largest gorilla – is fighting for survival.

Fauna & Flora International (FFI) has put out an urgent call to the global community to save the remaining 3,800 or so Grauer's gorillas.

Funds are sought immediately to help protect new community nature reserves that are essential to the survival of the remaining gorillas between the Maiko and Kahuzi-Biega National Parks in the Democratic Republic of Congo (DRC). It is a crucial step towards protecting these elusive and Endangered apes from complete extinction.

The Grauer's gorilla faces multiple threats to its survival – all of them due to human activity. A major expansion of agriculture and pastures in the DRC in recent years has put enormous strain on the gorilla's shrinking habitat. Industry, too, has taken its toll, with natural habitats squeezed by extensive mining for gold and coltan – a mineral used in making mobile phones. Hunting and the continuing consumption of illegal 'bush meat' have also caused many apes to be killed. What's more, continuous conflict has made it incredibly challenging to enforce wildlife protection.

As a result, numbers of Grauer's gorillas have plummeted. Just 15 years ago there were around 17,000 Grauer's gorillas in the wild. Today, scientists believe that at most 3,800 may still remain alive.

Conservationists are now calling for the species to be reclassified as Critically Endangered. We must act as quickly as possible to save the remaining gorillas and FFI needs your urgent help to do it.

FFI wants to protect existing gorilla families in a vulnerable – currently unprotected – area between the Maiko



Your donation has twice the impact

Thanks to the generosity of Size of Wales we are able to double all donations received up to £21,000. Please act now to help us make the most of this unique opportunity.

and Kahuzi-Biega National Parks. These families are vital to saving the remaining Grauer's gorillas from extinction.

This gorilla protection has only become possible in recent years. Since the elections in the DRC in 2006, and the increased stability that came with them, conservation teams are starting to consolidate a series of community reserves to ensure the gorillas are fully protected.

For the species to remain genetically viable, it is crucial that the gorilla families can interbreed and are not separated by deforestation and agriculture expansion in an unprotected area. FFI knows community managed land is a sustainable way to achieve this.



"The Maiko and Kahuzi-Biega National Parks in the DRC are home to some of the most endangered species in Africa, including the Grauer's gorilla. However, as human populations in the region expand so too does the risk from habitat loss. A participatory form of conservation is giving these communities a means to exist and is helping the Grauer's gorilla and other wildlife. Time is short and I urge supporters of FFI to quickly back this vital work that is crucial to the survival of the Grauer's gorilla."

Sir David Attenborough OM FRS, Fauna & Flora International vice-president

These community reserves are absolutely vital to the future of the remaining Grauer's gorillas – because they will prevent the gorilla population becoming fragmented.

To do all this FFI needs to raise £130,489.56 to protect $10,847.67 \text{ km}^2$ of forest, where the gorillas are at risk. The £130,489.56 must be raised as soon as possible so that the team at FFI have time to plan ahead.

Meanwhile unprotected gorillas are dying from the threats they face every day. The Grauer's gorilla is on the very edge of survival. Together we can save it. Please send your gift by 7 December at the latest.

wherever they are most needed

Registered Charity No.1011102. Registered Company No. 2677068.

One of the world's rarest apes faces extinction

Population plummets by 77% from 17,000 to around 3,800

Fauna & Flora International (FFI) have launched an emergency appeal to raise £130,489.56 from readers that will enable them to push ahead with the protection of new Community Reserves in the Democratic Republic of Congo. This is crucial to the battle to save the Endangered Grauer's gorilla from extinction. Please respond by 7 December to help us double your donation's impact with Size of Wales. Donate now by visiting www.supportgorillas.org or calling 01223 749019.

How you can help save the Grauer's gorilla

£130,489.56 is sought by 7 December to urgently protect a series of community nature reserves that will safeguard the gorillas in unprotected areas - where they are at risk of losing their habitat and being killed by hunters. These are a few of the items needed:

£19,180 could fund the entire DRC conservation team for 6 months.

 \pounds 679.15 could pay for a satellite phone, to help the teams report and respond to emergencies

 $\pounds 258.72$ could pay for a GPS unit and batteries, to help the teams locate gorilla families in the dense rainforest

£129.36 could pay for fuel to run the team's off-road vehicle for a month

 $\pounds 40.10$ could pay for rations for a gorilla survey team

Any donations, large or small, will be received with thanks and could go a long way to helping us to save the Grauer's gorilla.

Cut the coupon below and return it with your gift to FFI, to double your impact and help save the remaining 3,800 Endangered Grauer's gorillas. Alternatively, go to www.supportgorillas.org or call 01223 749019. Thank you.

I want to help save the remaining 3,800 Grauer's gorillas with a donation of £		
Title	Forename	
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	etails securely and will never sell, trade or rent your personal information to other you'd prefer not to be mailed or telephoned , please tick the appropriate box any time.	
	r: Freepost FAUNA & FLORA INTERNATIONAL, aborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK	
•	avegorillas.org.uk to donate online now. Flora International succeeds in raising more than £130,489.56 from this appeal, funds will be used	



THE THEORY OF (nearly) EVERYTHING

The big ideas and discoveries in science explained



In this special issue, the editors of BBC Focus Magazine explain the fundamental concepts of science, and reveal the latest cutting-edge research that will change our world.

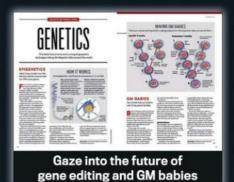
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- The Universe's history and how it will end
- Clear explanations of key scientific concepts
- Science facts, stats and expert opinion
- Stunning images of life on and off Earth

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HELEN CZERSKI... WHY DON'T CRÉPES CATCH FIRE?

"THE CHEF POURED FLAMING BRANDY OVER THE CRÊPE, MOUSTACHE TWITCHING AT OUR REACTION"



t dinner, I hadn't really been expecting pyrotechnics. One of my friends had decided that since we were in Brittany, crêpes should be hunted down at every opportunity. On the last night, he led us to a tiny restaurant, hidden behind curtained

windows on a quiet street and staffed by one man with a moustache worthy of Inspector Clouseau. After savoury crêpes for the main course (to my friend's delight, the menu lacked any other food type), it was time for dessert. Mine arrived last, and our chef poured flaming brandy over the crêpe at the table with a flourish, moustache twitching at our reaction to the shimmering blue blanket covering my plate. The flame was gone within a few seconds but it left a question. Why didn't it set the rest of the crêpe on fire?

When I tried it later at home, I met the first rule of flambéing food: you need to warm the alcohol before you can light it. Spirits such as brandy contain a range of molecules that provide flavour, but they are mostly water and alcohol. If you pour a measure of brandy out of a bottle, it provides a reminder that molecules are often pretty mobile - you can smell the stuff as soon as you take the top off. Both water and ethanol (the alcohol) are small molecules that will happily mix with each other. But the ones at the surface can escape the pull of the mob and drift up into the air. The warmer the liquid is, the more molecules have enough energy to escape. Every fuel has a temperature known as its 'flash point', which is the point at which the liquid is warm enough to release enough molecules into the air to sustain a flame. The flash point of a typical liquor is between 26°C and 30°C, which is not that high but it's still above room temperature.

And it's up in the air that the burning takes place, where the fuel can mix with oxygen. The temperature of that flame can be a few hundred degrees centigrade. That's enough to brown the crêpe a bit more, causing a few extra chemical reactions that could enhance the flavour. But the crêpe itself is made of carbohydrate, fat and protein molecules, all carrying stored chemical energy that could be released by burning. Why do the flames dance on top but never touch what's beneath?

The answer lies with the other component of the brandy: the water. Water can't burn, but it still has a



very important role to play here. Before it can reach the crêpe, the heat energy released by the flames heats up the liquid brandy, giving the water molecules enough energy to escape and become gas. But this transition from liquid to gas requires a huge amount of energy, so relatively little heat gets through into the crêpe itself. In addition, the steam produced helps to insulate the crêpe from the heat source above it. The rest of the crêpe is safe from burning because it just never gets hot enough, in spite of the very high temperatures hovering above it.

During my home experiments, I discovered that the heat getting to the inside of the crêpe was enough to soften chocolate, but certainly not enough to cook slices of banana. The flames are mostly cosmetic, and generally contribute very little to the cooking process.

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, is out now (Transworld, £8.99). **NEXT ISSUE: WHY ISN'T THE SHORTEST DAY ALSO THE COLDEST?**

Here in the UK we're more likely to light up a Christmas pudding than flambé a crêpe, and the science behind the pudding is pretty similar. Make sure you warm up the pudding thoroughly before setting the brandy alight – the flame may look great, but it really isn't cooking anything!





UNDERSTAND DE-EXTINCTION

Mammoths, Tasmanian tigers and even Elvis could soon be brought back from the dead, thanks to intriguing advances in cloning and gene editing. But would they be the real McCoy?

WORDS: HELEN PILCHER

Imagine travelling to the wilds of Siberia to see a woolly mammoth lumbering through its natural habitat. Or getting up close to a living, breathing Tasmanian tiger. Thanks to developments in cloning and genediting technology, the prospect of bringing back extinct animals is looking more likely than ever.

De-extinction is about creating populations of healthy, genetically vibrant animals that can be released into the wild where they'll be able to breed naturally and contribute positively to the environment. But it's not just about bringing back the dead. The same techniques being developed to help resurrect extinct species can also be used to help save living species on the brink of extinction.

So how does de-extinction work, what are its limits, and do we really need to bring back long-dead animals?

How feasible is de-extinction?

De-extinction is very much a science in development, but it's moving at a rapid pace. The first milestone was in 2003 when European scientists resurrected the Pyrenean ibex (or bucardo), a type of mountain goat that had gone extinct a few years earlier. Sadly, the kid died a few minutes after she was born, so the bucardo was not just the first animal to be brought back from extinction, but also the first to go extinct twice.

Since then, scientists have been refining their methods and developing new de-extinction techniques. In Australia, Prof Michael Archer and colleagues are working on bringing back the gastric-brooding frog, a

remarkable animal that nurtured its young in its stomach before burping up fully-formed froglets. So far, the team has produced embryos that 'almost' turn into tadpoles but not quite. The next step is to persuade these embryos to turn into frogs, something that Archer is convinced they will achieve.

What other animals could we make de-extinct?

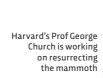
In America, scientists are working on bringing back the passenger pigeon, a rosy-breasted bullet of a bird that once flocked in the billions; and the heath hen, a stumpy avian wallflower that lived in the scrubby plains of New England. In the UK, researchers are considering whether or not to bring back the so-called 'Penguin of the North', the great auk. Meanwhile, in South Africa, they're trying to revive the quagga, a bizarre zebra-like creature with a stripeless behind! In South Korea, Japan and the US, three separate teams are racing to bring back that most iconic of Ice Age beasts, the woolly mammoth.

How do you 'de-extinct' something?

It depends on the species. Some projects use 'back-breeding'. Quaggas, for example, are related to living ●



Scientists are trying to bring back the gastric-brooding frog, which went extinct in the 1980s





• zebras. So scientists are choosing the zebras that look most like quaggas and letting them breed. The aim, over successive generations, is to create animals that look like quaggas. Other projects, however, involve assisted reproduction and some rather elegant genetics. Some are using cloning; others, stem cell science. For example, Prof George Church at Harvard Medical School aims to create a mammoth by 'editing' mammoth genes into elephant cells.

Will these animals be the same as the originals?

No, they can never be exactly the same. When he is done, Church will have created not a true mammoth, but an elephant with a sprinkling of judiciously placed mammoth DNA. It will have long, shaggy fur, thick rolls of insulating body fat, and haemoglobin that can ferry oxygen around the body at sub-zero temperatures. This will be an animal that looks like a mammoth, but is really an elephant whose DNA has been altered so it can live in the cold. You could call it a 'mammophant' if you like, or an 'elemoth'.

Added to that, we now realise that all animals are a product of their DNA and of the environment in which they live, along with the interaction between the two. Created in a lab, nurtured in the womb of a modern

elephant, and raised in a world that has changed radically since mammoths went extinct thousands of years ago, the experiences of this newage pachyderm will be different to those of its Ice Age doppelgänger... all of which will conspire to make it less similar to the original woolly mammoth. But does this matter? Many will argue that, if the de-extinct animal looks and acts like its predecessor, then that's good enough.

Could we resurrect dinosaurs?

Sadly, a real-life *Jurassic Park* is out of the question. There are limitations on which species can undergo de-extinction. First up, scientists need to have a source of the animal's DNA. Sometimes this comes from preserved museum specimens or from cells that have been collected from live animals and frozen away. Sometimes it can come from fossils. But DNA disintegrates over time, meaning that after a couple of million years there is simply no DNA left. Dinosaurs famously went extinct 65 million years ago, so their DNA is lost forever. No DNA, no dinosaurs.

And if you're hoping to meet a dodo, that icon of extinction, then don't hold your breath either. Although it died out comparatively recently – a few hundred years ago – its final resting place, Mauritius, was simply too hot to preserve its DNA. •



Although the dodo only died out in the 16th Century, we don't have any DNA samples to clone it

JARGON BUSTER

CLONING

This is one of the principle methods used to bring back certain animals. DNA from an adult cell is coaxed into a more youthful state, which is then used to create an animal that's almost genetically identical to the donor.

ECOSYSTEM

This is a biological community of interacting life forms and the space they live in. Healthy ecosystems are essential to the survival of life on Earth: they provide services including purifying the air, pollinating our crops and sequestering carbon.

GENE EDITING

The ability of scientists to alter the DNA of living things with pinpoint accuracy. The core components of DNA can now be removed, replaced or added to at will using a process called CRISPR Cas9.

RESURRECTION BIOLOGY

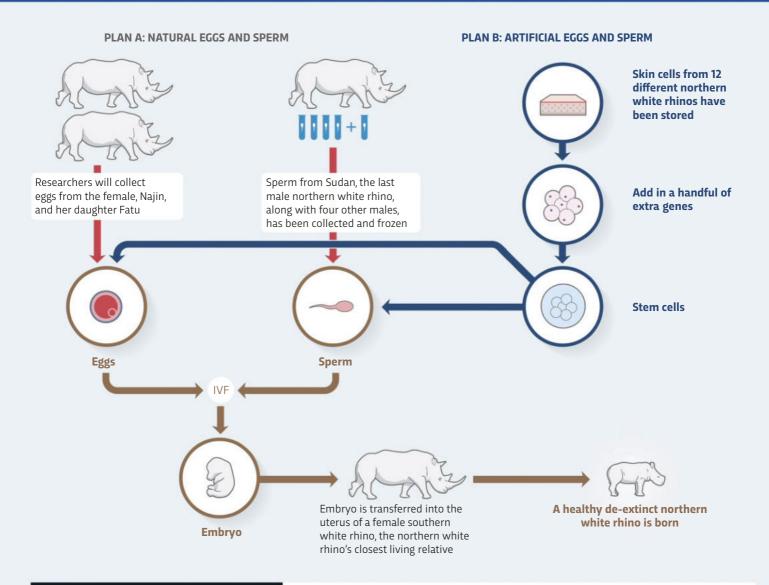
Another term for de extinction. This blend of high tech methods is enabling scientists to bring back species from the brink of extinction and beyond.

STEM CELL

These versatile 'shape shifting' cells can turn into other cell types. Scientists have made northern white rhino stem cells, and next plan to use them to produce eggs and sperm for rhino IVF.

HOW TO SAVE THE NORTHERN WHITE RHINO

The last three northern white rhinos are unable to breed naturally. A Berlin-based team hopes to de-extinct this animal using IVF and advanced stem cell biology



WHAT WE STILL DON'T KNOW

HOW CLONING WORKS

I Although we've been cloning animals for years, we still don't understand how it actually works. During the process, DNA inside an adult cell is somehow reprogrammed to a more youthful state, so that it can drive embryonic development. It's like restoring the factory setting on your phone, but no one knows exactly how it happens or how to fully control it. Crack that, and scientists stand a better chance of creating healthy, viable animals.

ANIMALS WILL BE PROTECTED

To qualify for legal protection, an organism must be listed as endangered, but for that, the animal must be living in the wild. The first few generations of any newly resurrected species would be kept in captivity while researchers checked their health, so during this time their legal status would be uncertain. Without protection, the animals could be threatened by poaching or habitat loss.

HOW DE-EXTINCT ANIMALS WILL FARE IN THE WILD

When it comes to releasing the animals, all we can do is study their previous ecology, and send them into the most suitable environment available. We'll then need to monitor them carefully: it's vital to know why a species went extinct first time round, to make sure it doesn't happen again. With each successive re-wilding attempt, we'll learn more about maximising the animals' chances of survival.

De-extinction, fast becoming reality, has the power to save species, shape evolution and sculpt the future of life on our planet.

O What's the point of de-extinction?

There are lots of good reasons to bring back extinct animals. All animals perform important roles in the ecosystems they live in, so when lost species are returned, so too are the 'jobs' they once performed. Woolly mammoths, for example, were gardeners. They knocked down saplings, ate grass and fertilised the ground via their nutrient-rich dung. But when they disappeared, the gardening stopped, biodiversity plummeted and the lush mammoth steppe was replaced by species-poor tundra. Studies suggest that if large grazers were returned to the far north, biodiversity would increase again.

It could be the same for other deextinct animals, too. De-extinction
provides a means to enhance
biodiversity and help restore the
health of ailing ecosystems. It could be
a conservation tool, and by choosing to
bring back animals that are genetically
unique – like the gastric-brooding frog
or the Tasmanian tiger (a stripy,
pouched, dog-like marsupial also
known as the thylacine) – we could
replace not just twigs, but entire
branches on the tree of life.

Then there are the benefits that humans could glean. The gastric-brooding frog somehow converted its stomach into a makeshift womb. It stopped producing stomach acid so it didn't digest its young. If scientists could figure out the changes involved in this, it could lead to treatments for stomach ulcers or could help people recovering from stomach surgery.

Every day, between 30 and 150 species disappear from the face of our planet, and studies reveal that extinction rates today are 1,000 times higher than they were during prehuman times. We live in a time of mass extinction, and de-extinction has been proposed as a key way to undo some of that harm. To reverse extinction would undoubtedly be a huge moment for the fields of biology and conservation, and a feat that could motivate future generations of scientists and wildlife defenders.



We could use DNA from preserved mammoths to create elephants with mammoth-like qualities

Where would the animals live?

De-extinction is a process that begins with creating a single animal in the lab and then ends, many years later, with the release and survival of sustainable populations in the wild.

Ecosystems are fluid, dynamic entities - they change quickly. But if a species has gone extinct recently, there is a chance it could be returned to its original ecosystem. The Tasmanian tiger is thought to have gone extinct 80 years ago, but in that time, its native woodland has stayed more or less the same - this de-extinct species could potentially 'go home'. A de-extinct Christmas Island rat, however, would not be so lucky. Since its extinction over 100 years ago, Christmas Island has become riddled with invasive species that would likely pose a problem. In this case,

a suitable alternative habitat would have to be found.

What is the ideal candidate for de-extinction?

It may seem an odd thing to say, but one of the ideal de-extinction candidates could be an animal that is actually still alive... just. There are only three northern white rhinos left alive on the planet: a grandfather, a mother and a daughter, who spend their days at the Ol Pejeta Conservancy in Kenya. But they are too old, too ill and too related to breed naturally.

So the northern white rhino is 'functionally extinct': the ghost of a magnificent species that once manicured the diverse African grasslands on which so many other species depend. Saving it counts as an

1 WE'RE TURNING BACK TIME

Scientists are on the verge of being able to reverse extinction. They are taking DNA from fossils and museum specimens, and using some fancy, high-tech science to make copies of various extinct animals.

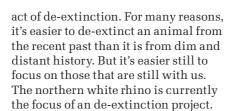
2IT'S ALL FOR A REASON

The idea isn't to create some lonely zoo exhibit or biological freak, but to generate entire populations of healthy animals that can breed naturally and live sustainably in the wild. Through their actions, and the positive effects they have on other species in their ecosystem, de-extinct species could help boost the overall levels of biodiversity.

A NEW ERA FOR CONSERVATION?

Despite the best efforts of conservationists, species are going extinct at an alarming rate. De-extinction is new, unfamiliar and untested, but it could become a vital instrument in the conservationist's toolbox. Over the coming decades, we'll be able to assess its worth and decide how, or indeed 'if', the technology should be used.

BELOW: Cloned boxer dogs jostle for attention at the Sooam facility in South Korea



But is it right to bring back extinct animals?

Some people are against de-extinction because they say it feels unnatural. They are wary of genetic modification and accuse scientists of playing God. But proponents argue that the techniques being developed to make de-extinction happen all have natural counterparts in the wild. For example, there are species of lizard that reproduce via cloning, while the gene editing process being used to bring back the mammoth hails from a primitive bacterial immune system.

Just as IVF has become an accepted medical technique, so de-extinction researchers hope that concerns about their experiments will fade once the science has proved its worth.

Critics also claim that de-extinction is stealing funds and attention from traditional conservation efforts. But none of the big wildlife charities are putting any money into de-extinction, and a big resurrection success story could even help to draw attention to the plight of the world's wildlife, rather than detract from it. It's true that it's still too early to know exactly

how de-extinction will pan out, but its supporters argue that if we don't at least develop the technology needed to

Could we bring back our pets?

genuine assessment of its worth.

make it happen, we'll never make a

Elvis's auiff would

be seething with

DNA that we could use to bring him

back to life

The labs at Sooam Biotech Research Foundation in Seoul, South Korea, regularly produce cloned dogs for the Korean National Police Agency and will even clone your pet pooch for around £65,000. But although the doppelgänger will look like your faithful friend, it will never be the same. Just as identical twins develop different personalities, physical characteristics and diseases, 'Fido II' will grow into a different dog.

And how about... Elvis?

If we can resurrect animals, could we bring back long-dead humans? In theory, it's possible. Take Elvis Presley as an example. Scientists could retrieve DNA from some of his iconic quiff, sequence his full genetic code, edit the 'genetic essence' of Elvis into a regular human cell and then use that to create a cloned baby.

In reality, though, it's a terrible idea. Reproductive human cloning is illegal and unethical, and the process carries many risks. What's more, a clone of Elvis might well end up more into drum 'n' bass and Dr Martens than rock 'n' roll and blue suede shoes.

But this cheeky thought experiment does show how far the science underpinning de-extinction can take us. Elvis? Maybe not. But woolly mammoths and Tasmanian tigers? Don't bet against it. •

Helen Pilcher is a science writer, performer and author of *Bring Back The King: The New Science Of De extinction* (£16.99, Bloomsbury Sigma).

DISCOVER MORE



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NEXT MONTH: HOW DO WE KNOW HOW THE SOLAR SYSTEM FORMED?



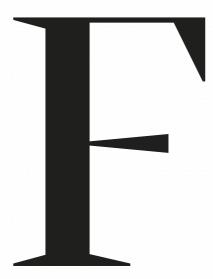


Should we get over GM food?

GM FOOD HAS BEEN AROUND FOR OVER 30 YEARS, YET IT STILL IGNITES HEATED DEBATE. SO IS IT SAFE, AND SHOULD WE ALLOW IT TO GRACE OUR SHELVES?

WORDS: PROF JIM DUNWELL

Jim is a professor of plant biotechnology at the University of Reading. His research areas include plant breeding, gene expression and protein evolution.



or most people, Miami is either a sun-drenched holiday destination or the favoured location for US crime dramas. However, in 1983, it was forever written in the annals of science as the place where it was first announced that we could introduce specific genes (pieces of DNA) into plant cells, then generate whole plants with only a single altered characteristic. Before that, plant breeders had been confined to crossing together two parents and then screening the resulting plants for that rare individual that emerged with better properties. This process was by its nature hit and miss and it took several years before a new variety with the desired properties could be bred. Suddenly it became theoretically possible to make specific alterations to an existing variety with relative ease. Thus began the age of genetically modified (GM) or transgenic agriculture.

From that point onwards a race began, headed by

Although GM seed is more expensive, the cost can be seen as an insurance policy against crop losses due to weeds and pests

US agricultural and agrochemical company Monsanto, to exploit this technology and develop novel varieties of crops. Understandably from a commercial perspective, the first targets were those predicted to generate the largest sales. The two dominant products were plants designed to be tolerant to herbicides - particularly the Monsanto product glycophosate - so weeds could be killed without harming crops, and those expressing toxin-encoding genes from the soil bacterium Bacillus thuringiensis (Bt) to give them resistance to certain insect pests. The strategy behind these approaches represented

something of a revolution. In the period immediately after WWII, research investment focused solely on the discovery of new herbicides and insecticides. But now, scientists could achieve the same effect by modifying genes within the crops rather than inventing new chemicals to spray on them. The first GM crops came to the US market in 1996 and sales grew rapidly.

It is estimated that sales of GM seed in 2015 amounted to \$15.3bn. This was grown in over 20 countries on an area greater than 440 million acres — more than a 100-fold increase since 1996. In 2015, the top five countries in order of area of GM crops cultivated were the USA (175 million acres), Brazil, Argentina, India and Canada. In the USA, more than 90 per cent of all maize, soybean and cotton is GM. In contrast, only about 290,000 acres were grown in the EU (mostly in Spain); all were an insect-resistant variety of maize.

DIFFERENCE IN OPINION

Although GM seed is more expensive than conventional equivalents, the extra cost can be seen as an insurance policy against crop losses due to weeds or pests. No longer is it necessary to spend so much time and money on the application of repeated sprays of herbicides or insecticides.

So why have EU farmers not taken the same route? The answers are based on differences in both the supply of GM seed and the demand for it. First, the range of crops differs between the two regions, with very little soybean being grown in Europe. Perhaps more importantly, attitudes to GM crops and to food derived from such crops are different on the two sides of the Atlantic. In the US, agriculture takes place mainly in regions that are far removed from the main centres of population, and who also have a general acceptance of government policy to GM.

In Europe, however, there is much greater awareness of farming locations as people tend to live closer to agricultural areas. In many countries, •

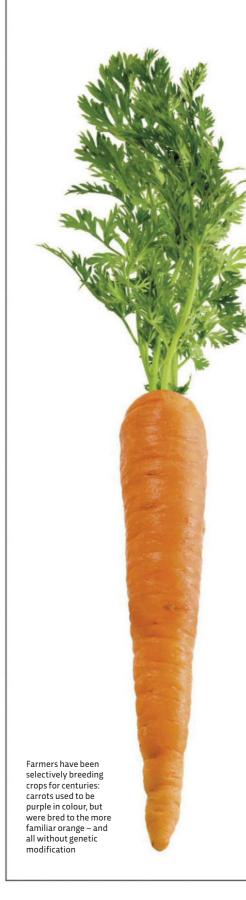


- 1 Different genetically modified strains of soybean are being grown in this field in lowa
- **2** Genes from this soil bacterium, *Bacillus* thuringiensis, can be inserted into crops to make them resistant to certain insect pests
- **3** A researcher in Minnesota attends to an experimental crop of GM corn





PHOTOS: GETTY, SCIENCE PHOTO LIBRARY



there is also a greater distrust of government and the regulations surrounding GM. But these these views are not held uniformly across Europe. Such diversity, allied to the complex politics within the present 28 EU member states, means that few GM crops have even been approved for cultivation. This has led to the withdrawal of commercial investment in GM in Europe, to be redirected to the US or Southeast Asia. This continues the trend of rapid commercial consolidation, to potentially just three massive conglomerates in the future – a significant issue to many who see commercial domination of agriculture, including GM, as detrimental to fair competition and a threat to livelihoods in the developing world.

ARE GM FOODS SAFE?

In addition to opposition based on the perceived danger of concentrating commercial power in fewer hands, there is also vocal criticism of GM on the grounds of food and environmental safety. But is there any evidence of this? First, it is helpful to consider the origin of the crops that we eat. Many farmed crops are genetic mutations of their wild ancestors, with such spontaneous mutations having been identified as occuring between 10,000 and 20,000 years ago, when humans moved from hunting and gathering to farming. These mutations led to dramatic changes in characteristics. For example, wild species of potato often contain toxic levels of chemicals called glycoalkaloids - compounds that protect them from insect attack. Similarly, the amount of edible fruit in a wild tomato is much smaller than in their farmed counterparts.

Our recent ability to sequence the DNA of crops has led to interesting findings about these evolutionary processes. It is now clear that genomes have continually been gaining and losing genes. The gains have often come from other species, as part of a process known as 'horizontal gene transfer'. Humans, for example, contain approximately 50 genes transferred from other organisms, including 27 genes from a diverse range of viruses. We should therefore consider the genomes of organisms not to be fixed, but subject to gradual change.

But do any of these genetic changes, whether naturally induced or brought about by humans, have an impact on food safety? Every part of our body, from skin to bones, and from blood to brain, is composed of chemical constituents obtained by the breakdown and reassembly of food. The DNA and proteins in food from GM crops have exactly the same chemical building blocks as those found in any other food. Over the last 20 years there has been no confirmed harm to the millions of humans that have eaten GM food, whether as fresh fruit such as papaya, or as processed products from maize, soy, sugar beet or oilseed rape.

In fact, the main global food safety issue is with food-borne diseases caused by contamination, principally with bacteria such as *Salmonella* and *E. coli*, viruses, parasites, toxins, and chemicals. In 2015, the World Health Organization (WHO) produced the first ever estimates of the global burden of foodborne diseases, and showed almost 1 in 10 people fall ill every year from eating contaminated food and 420,000 die as a result. This also has a significant economic impact. Germany's 2011 *E. coli* outbreak, which caused 50 deaths after consumption of sprouted organic fenugreek seed, reportedly led to \$1.3bn in losses for farmers and industries and \$236m in emergency aid payments to 22 European Union member states.

Some people are concerned about the potential danger posed by the spread of introduced genes from

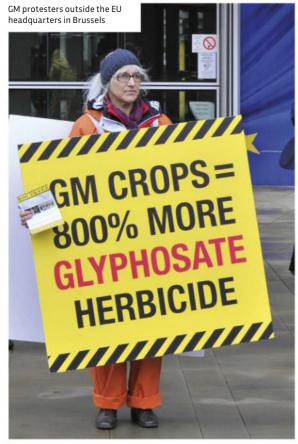
Over the last 20 years there has been no confirmed harm to the millions of humans that have eaten GM food

GM crops to their wild relatives. Such 'genetic pollution' is seen as irreversible and a threat to species diversity or stability. Although the gene that codes for herbicide resistance has been shown to transfer in the pollen of a GM grass to a wild relative, this has no environmental consequence. Also, a low frequency of pollination is known to occur between cultivated crops and their wild relatives and vice versa.

In most industrialised countries, and in many parts of the developing world, there are government •









• regulations that cover the import and cultivation of GM crops, and guidance on whether or not the food derived from GM crops has to be labelled. In the EU and US, the regulation applies to the *process* by which a GM organism is produced. In contrast, regulation in Canada focuses on the *product* generated, not the method by it was produced. Many scientists around the world now consider that the logical target of regulation should be the product and not the process, because this approach could accommodate all the new breeding technologies that have been developed in recent years.

THE FUTURE OF GM

We have the somewhat contradictory situation in Europe that only a tiny area of farmland is used for cultivating GM crops, yet about 90 per cent of imported soybeans – a major constituent of animal feed – come from GM sources. This means that people in the EU indirectly consume a large amount of GM because many animals eat imported GM feed. Meat, milk and eggs from animals fed on these products are sold throughout the UK, but do not need to be labelled as GM. In contrast, products for direct human

Meat, milk and eggs from animals fed on GM products are sold in the UK. Such products do not need to be labelled consumption are labelled as containing GM ingredients. In the US, however, once a product has received regulatory approval it is considered equivalent to that from a non-GM source and doesn't need to be labelled.

Several economic studies have shown that removing GMOs from the foodchain would have a significant impact. One carried out at Purdue University in the US earlier this year found that if GMOs were eliminated, there would be lower crop yields and commodity prices would rise. Corn (maize) prices would increase by as much as 28 per cent and soybeans by up to 22 per cent. In real terms, shoppers could expect

their food prices to rise by between 1 and 2 per cent.

A similar study carried out at North Carolina State University in 2015 found that if someone in the US wanted to convert to a GM-free diet, then when directly compared item by item, GM-free food costs an average of 33 per cent more than a comparable food item that is not GM-free. When compared on a per-ounce basis, GM-free foods cost an average of 73 per cent more. Generalising to the cost of a typical basket of food consumed by US households, the consumption of GM-free food would increase the average family food budget from \$9,462 to \$12,181 per year.

So what is the status of GM technology now that it is approaching middle age? Will it soon die out, as predicted by its opponents, to become a mere side note in agricultural history? Or will it flourish further and help to contribute towards feeding future billions? Based on objective evidence, the great majority of international scientists deem the technology to be safe, while also acknowledging that some parties may have socioeconomic and/or ethical grounds for opposition. Regardless, research continues apace. There are dozens of new forms of GM and gene-edited crops, and a few animals, currently being developed. These include non-browning apples and potatoes, purple tomatoes packed with extra nutrients, and even the AquaBounty salmon – a fish genetically modified to grow throughout the year rather than just in the spring and summer, making it cheaper to produce and lessening its environmental impact.

These products will possibly have more direct benefit to the consumer than the previous products aimed primarily at the farming industry. In the UK, it is possible that new legislation will encourage a more logical and proportionate regulatory system that might allow the scientific talent in this country to be used more effectively. But only time will tell whether this happens and GM technology leaves a legacy in the form of another generation of science. •

DISCOVER MORE



Read a BBC iWonder article about whether science can improve the nutrition of millions of people at bbc.in/IvsozVU



ROBERT MATTHEWS ON... RADIATION

"COULD IT BE THAT LOW DOSES OF RADIATION ARE NOT JUST HARMLESS, BUT POTENTIALLY BENEFICIAL?"



ention of the word 'nuclear' has a habit of making people go precisely that. From weaponry and exploding reactors to climatic upheaval,

a mere mention of the word comes with more baggage than a Mafia boss on tour.

Its reputation is so bad that during the 1980s doctors started talking to patients about 'magnetic resonance imaging' (MRI), because the scanning technique's original name – Nuclear Magnetic Resonance (NMR) – proved too scary for many.

The word 'nuclear' appears in NMR simply because the images are created using radio signals from hydrogen nuclei in our bodies. As such, it poses about as big a radiation threat as a toaster.

The irony is that many of those same patients wouldn't think twice about undergoing a nice, familiar CAT scan. Yet this type of imaging really does involve ionising radiation, the type that damages cells.

But now that's also beginning to change. People are increasingly asking questions about this technique with its cuddly-sounding name. And small wonder, given the claims that it exposes patients to radiation levels similar to those produced by the atomic bombing of Japan in WWII.

Yet at the same time, some scientists insist that the threats of radiation from CAT scans have been exaggerated. Now the US Nuclear Regulatory Commission (NRC) is considering loosening the risk standards. What's going on?

Everyone agrees that high doses of radiation pose a substantial health threat, and some of the best evidence for that comes from atomic bomb data. But to use it in the medical scanning debate is misleading.

First, while there was indeed a spike of cancer cases in some of the bomb victims, it occurred among survivors exposed to far higher doses than those experienced by patients during routine medical scans.

Using it in a comparison with medical scanning is like insisting that we should never drive faster than 5km/h because nobody survives a crash at 500km/h.

Actually, the comparison may be dodgier still, as ongoing studies of the bomb survivors have revealed that those exposed to relatively low levels of radiation have unusually low rates of leukaemia.

Could it be that low doses of radiation are not just harmless, but potentially beneficial? That's the claim made by proponents of a phenomenon called 'radiation hormesis', some of whom have now persuaded the NRC to look again at the risk figures.

Based on the Greek term 'to excite', hormesis is familiar enough from immunisation, in which vaccines made from viruses are used to stimulate our disease-fighting immune system. And in theory at least, it seems plausible that something similar may work with radiation. After all, we evolved on a planet seething with natural radioactivity.

Until now, all this has been given little credence by regulators who prefer to err on the side of caution, and assume that the only safe level of radiation is no radiation at all. This seems fair enough, until one realises that misplaced fear has its consequences too. The Chernobyl disaster that took place in 1986 was followed by thousands of unnecessary abortions of healthy foetuses, prompted by scare stories about risks to pregnant women.

It's unlikely that the NRC will change its guidance

on radiation exposure any time soon as the evidence isn't strong enough for so controversial a move – at least, not yet.

But that shouldn't stop anyone worried about a medical scan from doing the rational thing when faced with any uncertainty, and asking for a clear statement of the risks and benefits. •

Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest books is Chancing It: The Laws Of Chance And How They Can Work For You (£14.99, Profile).

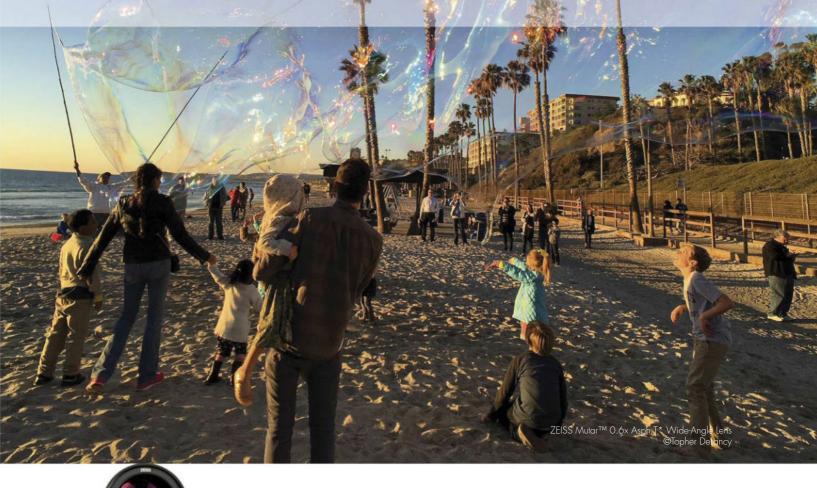
NEXT ISSUE: WHY WE SHOULD ALL DO MORE EXERCISE



CHRISTMAS GIFT GUIDE

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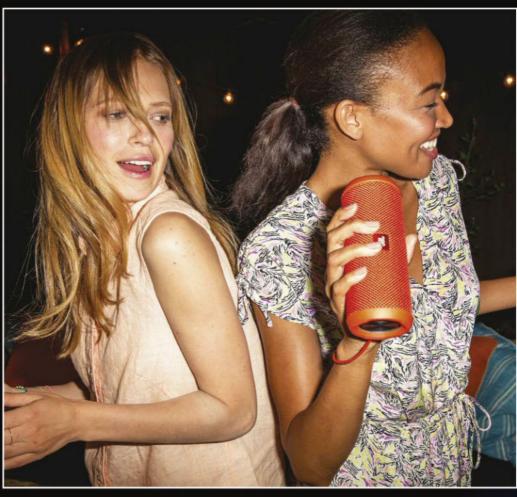


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JBLs' E45BT on-ear Bluetooth headphones bring up to 16 hours of battery, an innovative, stylish fabric headband and ergonomic on-ear design. This means that your entertainment continues and your fun factor gets amped up no matter what you're doing - working, commuting, or just making your way around town.

With the JBL E55BT wireless over-ear headphones have ergonomic around-ear design with a sleek appearance, various colour options and the added convenience of a detachable cable with remote and microphone too. Multi-device connectivity allows you to seamlessly switch between two devices, so you never miss a call and up to 20 hours of battery life you'll never want to be seen without your E55BT headphones.





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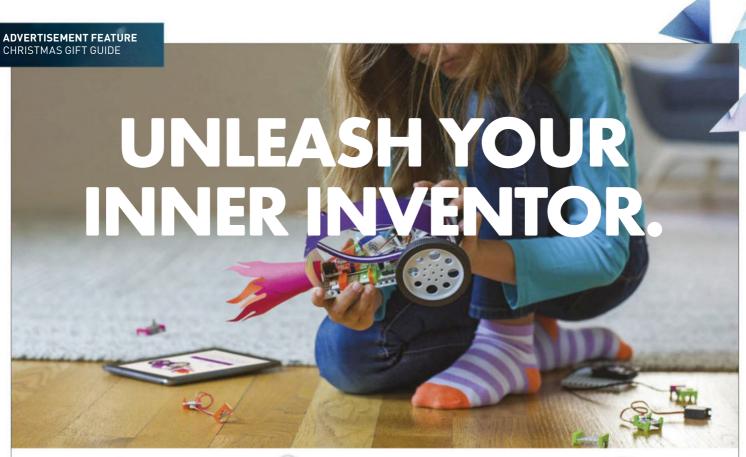
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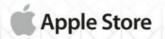
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IN ADMIRATION OF MUSIC

DALI KATCH. BORN TO BE A MUSIC MAKER

Introducing the DALI Katch, the wireless Bluetooth speaker that proves heritage matters

Danish high-end loudspeaker specialist DALI has launched its first-ever compact Bluetooth portable speaker.

Setting fresh standards in portable audio, the stunning new KATCH is the ultimate embodiment of DALI's advanced digital technology and unique design know-how, bringing both elements together to create a loudspeaker that delivers incredibly rich sound from a ridiculously compact chassis.

Under the extruded aluminium hood sits a Class-D amplifier (capable of pumping out some 2×25 w), 2×21 mm soft-dome tweeters and 2×3.5 -inch aluminium woofers, one pair facing front and one pair at the rear. The result is portable audio with real punch and a refined, involving sound that's perfectly balanced, even at the highest volumes.

Getting the party started with the KATCH couldn't be easier – Bluetooth 4.0 with Apt-X gives a wireless connection within seconds, while the NFC option is even quicker.

And keeping all options open, DALI has included a stereo mini-jack input, while the KATCH's USB charge connector means you can drive a Chromecast Audio dongle too, integrating your KATCH into your home network.

And keeping the party going isn't a problem, either, thanks to the KATCH's powerful 2600 mAh internal battery and power-level indicator lights; charging to full within 2-hours with the supplied charger, the KATCH then offers up to 24-hours of untethered playback.

Beautiful to behold, the KATCH is finished in an extruded aluminium body with ABS/polycarbonate front, complete with a sliding leather strap for easy carrying, plus a travel bag to keep the KATCH protected on the move. Who said brains and brawn don't go together?

Available in three striking colour schemes, Dark Shadow, Cloud Grey and Green Moss, the DALI KATCH blends elegantly and effortlessly into any environment.

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Christian is a psychology and neuroscience writer. His latest book is *Great Myths Of The Brain*.



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Alastair is an astronomer at the Jodrell Bank Centre for Astrophysics at the University of Astronomer at Aston



ROBERT

MATTHEWS

DR PETER J BENTLEYPeter is a

Robert is a physicist and and science a visiting university professor in science at Aston university. Digitized.



LUIS VILLAZON

Luis is a freelance science and tech writer with a BSc in computing and an MSc in zoology from Oxford University.

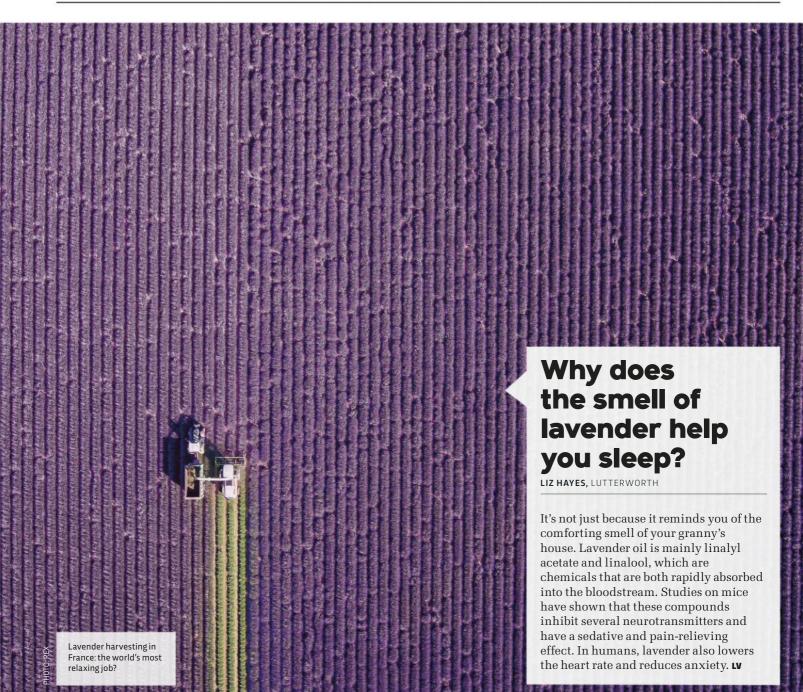


ALEXANDRA CHEUNG

Alexandra
has a degree
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ng has worked
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ord College
y. London.

YOUR QUESTIONS ANSWERED

DECEMBER 2016 EDITED BY EMMA BAYLEY







Does chicken soup really help a cold?

SUSAN GREY, GLASGOW

There is some evidence for this. Several studies have found that something in chicken soup interferes with the ability of white blood cells to flock to the scene of an infection. Since these white blood cells are responsible for the inflammation of your throat and sinuses, chicken soup may help to relieve the symptoms, even if it doesn't actually cure the infection.

How fast could you cycle in a vacuum?

CAROL JAMES, LONDON

When you ride a bike normally, the wind resistance increases with the cube of your speed. At 32km/h, the power needed to overcome the drag accounts for more than 75 per cent of the total cycling effort, and this rises to over 80 per cent at 40km/h. Recumbent bikes, which have much lower profiles to reduce their wind resistance, can already reach speeds of over 80km/h. If you removed air drag completely, the only friction would be from the tyres and the bearings. Provided you had a high enough gear ratio to allow your legs to pedal at an efficient pace, you could probably reach well over 150km/h. An easy way to simulate this would be to try pedalling on a stationary bike, but there are no published records for this sport. LV



IN NUMBERS

16

The number of days after conception that a human embryo's heart could start beating.

2,500

The distance, in kilometres, that autonomous sub Boaty McBoatface will travel under the Arctic sea ice.

7.74

The time, in seconds, of the longest ever lightning flash. It occurred in France in 2012.



Why is space three-dimensional?

NATHANIEL HEY, JERSEY

In principle, it's possible for the Universe to have many more space dimensions; some attempts to explain the fundamental forces of nature assume no fewer than six extra ones. Yet for reasons still unclear, any additional dimensions that may have existed at the Big Bang somehow failed to take part in the cosmic expansion and remained far smaller than the three dimensions we inhabit. What is certain is

that, had they grown in size, the Universe would be a very different place. Theoreticians have shown that any extra dimensions would make atoms unstable, while any fewer would eliminate the force of gravity. Max Tegmark, a cosmologist at the Massachusetts Institute of Technology, has gone further, arguing that the very fact we exist to ask about extra dimensions of space proves they don't exist. RM



SAM GORMLEY, VIA TWITTER

Fundamentally, and ignoring the complications of Einstein's Special Relativity, it's the same time as it is here on Earth. But this is a bit of a cheat, of course, because we haven't defined how we are measuring time.

There are many ways to define the 'time' at a particular location. Here on Earth our usual system ('solar time') is defined by the motion of the Sun in the sky (although we usually keep track of time with an atomic clock). This means that the local time depends on where you are on Earth and we get around this

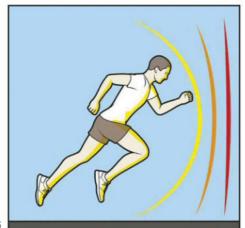
complication by having many different time zones. Now, we could also define a similar time system based on the motion of the Sun as seen from the Moon. Such a system exists (Lunar Standard Time) but it is not much more than an interesting exercise in physics. What is more useful, however, is a definition of time that doesn't vary with location. This is called Universal Time (UT) and is a modern form of Greenwich Mean Time. It is the same everywhere in the Universe. So, the UT time on the Moon is the same as the UT time on Earth. AG

Clock wondered if he'd done something to upset everyone



THE THOUGHT EXPERIMENT

HOW FAST WOULD I HAVE TO RUN TO CATCH FIRE?



1. ATMOSPHERIC COMPRESSION

At high speeds, it isn't friction with the air that produces most of the heat, it's the compression. Like a ship moving through water, you push a bow wave of air in front of you. The air molecules can't get out of the way in time and they bunch up, banging into each other and getting hotter. Any parts of your body facing into the wind will be heated up.



2. HYPERSONIC

The best place to run would be a long beach, like Pendine Sands in South Wales. The air is denser at sea level, which means there are more molecules to compress and heat up. Bodies are typically cremated at around 1,500°C and aircraft research from NASA reveals that you'd need to be running at Mach 5 (6,000km/h) to reach that temperature.



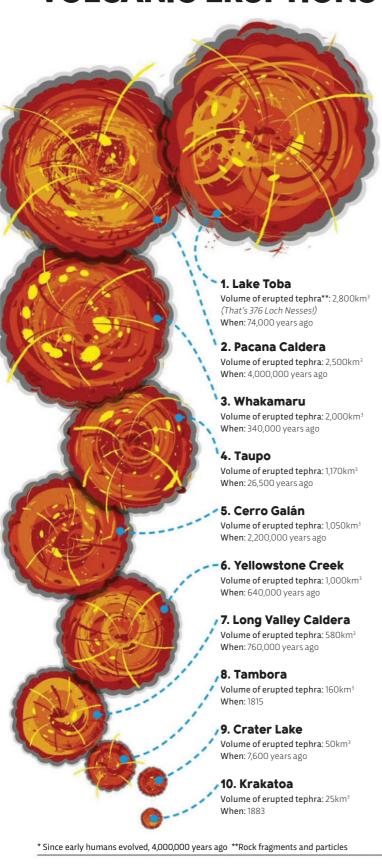
3. WRAP UP WARM

But that's the temperature to completely incinerate your entire body – your clothes will catch fire long before you reach that point. Nylon has an ignition point of about 500°C and wool will catch fire at 230°C. Which means that with the right attire, you could trot along at a leisurely 2,500km/h and still burst into flames.



TOP 10

MOST EXPLOSIVE VOLCANIC ERUPTIONS*





Why does cold weather make joints sore?

MARY DENNIS, BOURNEMOUTH

There is a psychological link: people who claim the weather affects their joints do feel more pain than those who don't make these claims. If weather sensitivity was a purely physical phenomenon, then people would be affected whether they believed that the variability was related to the weather or not. But a 2007 study also found that every 10°C drop in temperature resulted in worse arthritis pain. This may be because cold weather causes changes in the fluid that lubricates each joint. LV

Why do knots weaken a rope?

BOB NEVIS, MANCHESTER

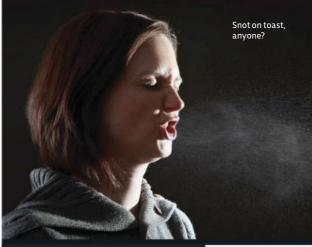
Anyone who relies on the strength of a rope takes great care to prevent knots forming in it, as they can reduce the breaking strength by more than 50 per cent. The reason is that knots create curved regions of rope whose outer circumference is greater than the inner part. This difference in length creates stress across the rope's width when put under tension, undermining its strength. RM



PHOTOS: GETTY, ISTOCK ILLUSTRATIONS: CHRIS PHILPOT

JILL SMYE-WALDENHURST, LITTLE HORNING

Most people's don't... but a significant minority do report a sweet or floral smell when they sneeze. This could be the smell of ketones from your bloodstream, which might be a sign of diabetes. But it is much more likely to be the cocktail of chemicals produced by the bacteria living in your sinuses or ears. Be grateful that yours smell of honey - some people's sinus bacteria give them the sneeze equivalent of halitosis. LV



Could melting icecaps generate earthquakes?

JOHN WILDES, IRELAND

Earthquakes occur when the huge tectonic plates that make up the Earth's crust slip and grind past each other along faultlines. In areas of land with thick ice cover such as Greenland or Antarctica, the immense weight of a layer of ice a few thousand metres thick may prevent plates from moving freely. If this ice were to melt, the plates could shift, releasing pent up energy and potentially triggering a quake. Although geologists have traced some small earthquakes back to loss of ice, it remains unclear whether larger tremors follow the same pattern. Ac

QUESTION OF THE MONTH

Are humans naturally monogamous?

LOIS ALED. VALE OF GLAMORGAN

Humans aren't sexually monogamous in the sense that many birds are. Geese form lifelong couples and virtually never mate with anyone except their partner. We are termed 'socially monogamous' by biologists, which means that we usually live as couples, but the relationships aren't permanent and some sex occurs outside the relationship.

There are three main explanations for why social monogamy evolved in humans, and biologists are still arguing which is the most important. It may be because human babies need a lot of looking after and stable couples can share the parenting burden. Or it could be because men want to stay close to prevent their partners from cheating. And it could also be a strategy that women evolved to discourage men from

killing infants that they suspected were not theirs. Monogamy in humans is beneficial because it increases the chances of raising offspring, but it is actually very rare in mammals - less than 10 per cent of mammal species are monogamous, compared with 90 per cent of bird species. Even in primates, where it is more common, only about a quarter of species are monogamous. Our early ape ancestors weren't monogamous and the practice probably didn't take off until Homo erectus emerged, around 1.9 million years ago. LV





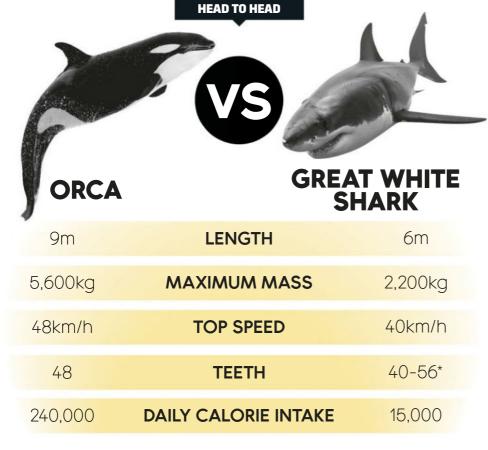
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Is hacking getting harder?

LEN GOODALL, LEICESTER

Computer security is becoming more and more advanced, and computer systems are complicated, so it is a more difficult task to attack or intrude into well-established computer networks. In this respect, hacking is more difficult and requires greater expertise compared to 20 years ago. However, there are more and more internet-

enabled devices in the world, many of which run relatively simple software. Therefore, there are endless opportunities for hackers to exploit the security loopholes in central heating controllers, smartwatches, websites, smartphones, games consoles, CCTV cameras, vehicle controllers or even electronic toilets. PB



Although the great white shark has a fearsome reputation, in a straight fight it is outclassed by the orca. Not only are orcas much bigger, they are also smarter. Great whites are now known

to be warm blooded but orcas still have much higher metabolic rates because they breathe air. In the wild, orcas have been seen preying on great white sharks.

What is the greenest energy source?

MIKE NEWELL, CARDIFF

All renewable energy sources are strong contenders for the title of 'greenest energy source' since they harness carbon-neutral sources of energy such as the Sun or wind and don't cause air pollution, putting them leagues ahead of coal or gas power. Picking a clear winner is, however, tricky. Once you consider the emissions associated with their manufacture and installation, hydropower has the lowest carbon footprint, according to one major study. But there are also many other environmental impacts to bear in mind. For example, building hydropower dams can cause disruption to river ecosystems, while manufacturing solar panels typically involves toxic chemicals. AC



^{*} Exposed teeth at one time. Great whites have further rows of developing teeth behind the visible ones.





Do we all see the same colours?

IAKE BOGDAN. SWITZERLAND

A minority of people are 'colour blind', in that they see colours as duller than usual and have difficulty distinguishing certain colours. These problems aside, whether your experience of red is the same as mine is a tricky philosophical question because we can never truly know each other's subjective experience. What's for sure is that the same object can be perceived as being a different colour by different people, depending on the assumptions their brains make about the background lighting. Just look at the ferocious internet argument in 2015 over whether a striped dress – pictured on Tumblr – was white and gold or blue and black (Google 'the dress' to read more). **q**

Are left-handers smarter?

PRANEETH VITHARANA, SRI LANKA



The idea that left-handed people are more intelligent than right-handers is a myth. There have been lefty geniuses in history like Leonardo da Vinci, but this is not part of a larger pattern. If anything, the opposite is true. In 2015 Dutch researchers combined the results from over 30 previous studies involving over half a million people and found no link between handedness and verbal ability and a small advantage for right-handers in terms of spatial ability. Another recent study based on data from tens of thousands of people actually found that left-handedness was more common among people with very low IQ than among people with typical IQ. **q**

Why do phone batteries explode?

OLIVIA ANDERSON, BOURNEMOUTH

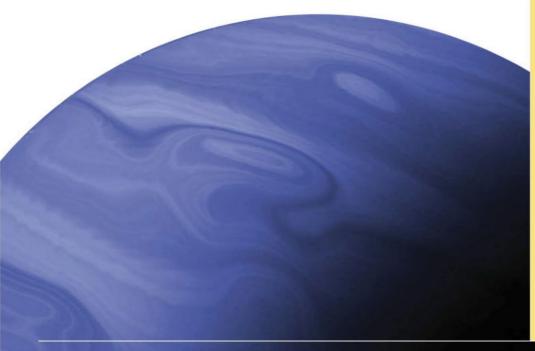
Lithium ion batteries have two electrodes sandwiching a layer of flammable organic solvent electrolyte between them. Mobile phone batteries are so slim that the gap between the wide, flat electrodes is tiny. In the case of the Samsung Galaxy Note 7, manufacturing defects squashed these electrodes and allowed them to touch. When that happens, the battery short circuits and creates lots of heat. This speeds up the chemical reactions, which generate even more heat, leading to a thermal runaway condition. Lithium batteries can also catch fire if they are overcharged, or charged below 0°C. This causes lithium metal to build up on the negative electrode, which will also eventually cause a short circuit. Protection circuitry in the battery is supposed to prevent this, but this can also fail. LV



Could Earth once have been a gas giant?

ADRIAN SHIPPEY, BRISTOL

The traditional view of planet formation is of a gas cloud collapsing, fragmenting and condensing into planets, with gas giants generally forming far away from the star where more volatile compounds are found. But, another process, called 'tidal downsizing', envisages larger gas clouds forming much further out from their stars. These coalesce into massive gas giants, with sizeable rocky cores, and then migrate inward towards the parent star, eventually losing their gaseous envelopes. Although the theory is in its infancy and much of the details remain to be worked out, there is a possibility that the Earth could have formed from a gas giant in this way. AG



WHAT CONNECTS...

...GAS STREET LIGHTING AND NUCLEAR POWER?

used before.

In 1885, Austrian scientist Carl Auer von Welsbach invented a new form of gas lighting which produced a much brighter light than the ordinary flame lamps

The lamps introduced by von Welsbach surrounded the flame with a thorium oxide mantle. Thorium oxide has a 3,300°C melting point, which lets the mantle glow white hot without melting away.

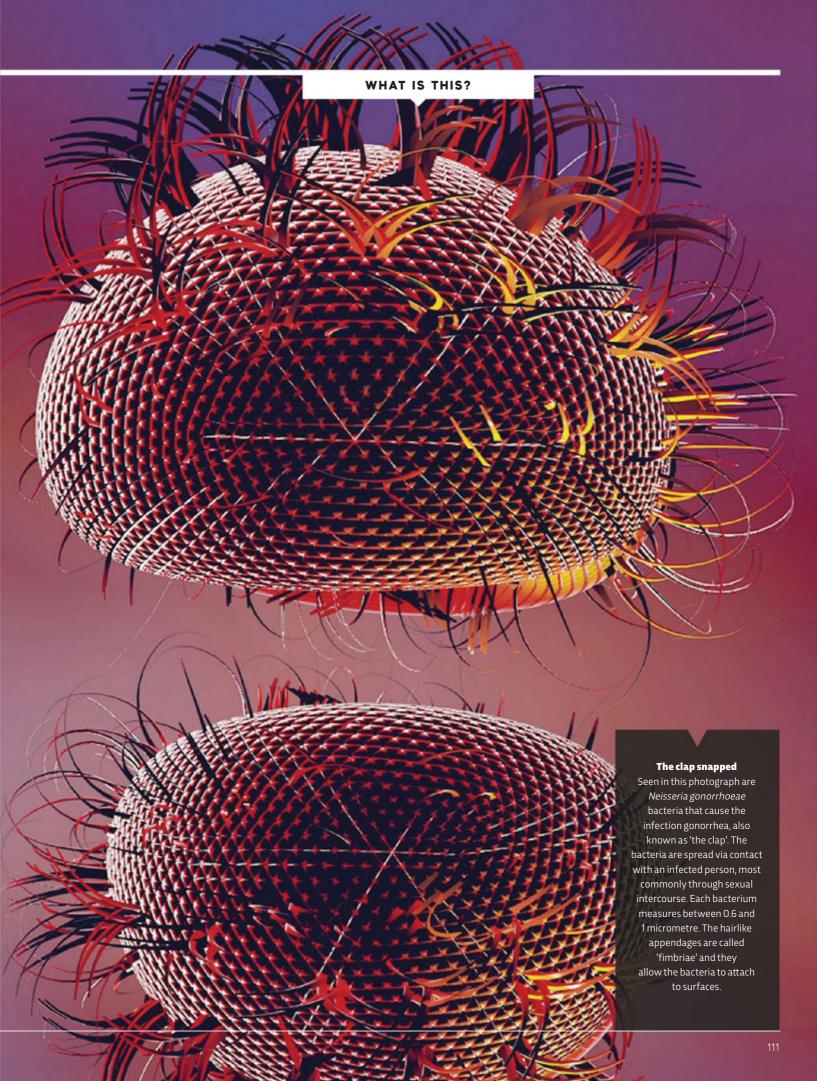


Unfortunately, thorium is also radioactive and decays to radon-220, which is also radioactive. Using a thorium gas lamp isn't dangerous, but old gas mantle factory sites have problems with contamination.

4.

For nuclear reactors, thorium is a safer alternative to uranium or plutonium. Thorium can't be weaponised, and its high melting point makes it less prone to catastrophic meltdown.

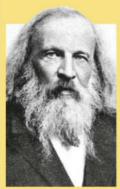






WHO REALLY INVENTED?

THE PERIODIC TABLE





DMITRI MENDELEEV

JOHN NEWLANDS

On the wall of every school chemistry laboratory is a poster of the periodic table of elements. It has been the go-to reference on chemical elements for almost 150 years. Yet while the Russian chemist Dmitri Mendeleev is often credited with finding the rules behind the block-like patterns of elements, he was hardly alone: others had found them some years before, but failed to win recognition.

One of these scientists was John
Newlands, an English chemist who in
the mid-1860s pointed out that
elements with similar properties lie
close together if arranged according to
their atomic mass. But in describing his
findings to fellow scientists, he drew
parallels with octaves of musical notes,
which prompted howls of derision.
Newlands' discovery had in any case
been presaged by the work of another
English chemist, William Odling, but he
too failed to garner much interest.

Mendeleev's claim to fame lies in the fact that he realised that the patterns were more complex than others had realised, leading to some columns on the table being longer than others. He also suspected that gaps within the resulting blocks implied the existence of as-yet undiscovered elements, and bravely attempted to predict their properties. His confidence was vindicated with the discovery of gallium, germanium and scandium, ensuring his place among the great names of 19th-Century science. RM



If you fell into a black hole, would time feel really slow?

REECE SHANKS, AGE 9, SCOTLAND

No, because you have no way of 'feeling' the passage of time. It is true that large gravitational forces (such as when you approach a black hole) slow down time, but you can only be aware of this by comparing your experiences with someone far away from the black hole. You will see a distant friend

'sped up' rather than feel yourself
'slowed down'. They will see you
'slowed down' rather than feel
themselves 'sped up'. The closer you
approach the black hole's 'event
horizon' the more sped up you see your
friend. But for you, time would 'feel'
just as it does to you right now. AG

PERLAN 2 GLIDER

This sailplane will fly at an altitude of over 27,000m (90,000ft) to study weather patterns, climate change and the ozone. The glider will operate in atmospheric conditions similar to those on Mars, so its tech may help us explore the Red Planet

The two-person crew will breathe pure oxygen

As it has no engine, the Perlan 2 will not pollute the environment Mountain waves are updraughts that form when winds cross a mountain range at a perpendicular angle. The glider 'surfs' the mountain waves to achieve lift

The Perlan 2 has a 25m wingspan and has a mass of 573kg when empty

The Perlan 2 will set a new altitude record and will experience temperatures of -70°C



Does rain ever fall as pure water?

CLIVE DANIEL, TROWBRIDGE

No. Water is an excellent solvent and rain always contains dissolved gases from the atmosphere. Even in a remote, pollution-free region, rainwater will still be slightly acidic because carbon dioxide in the air reacts with water to form carbonic acid. Rainwater isn't even pure when the raindrop forms, because each drop precipitates around a speck of dust, or an airborne bacterium.

Does the speed of light ever change?

JACKIE TAUNTON, READING

Light has long been known to slow down whenever it passes through a medium such as air or glass. Light also interacts with the molecules in its surroundings. But over the years, some theorists have proposed that the speed of light in a vacuum may have been far higher during the Big Bang. While this would solve some of the technical problems concerning the early Universe, there's no compelling evidence that this is the case. RM



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ROBIN INCE ON... CHRISTMAS SHOPPING

"WE STUMBLE THROUGH ARTIFICIALLY LIT DOMES, **LUNGING FOR SOFAS AND LAPTOP ACCESSORIES"**

he surrealist artist and anthropologist Desmond Morris once wrote that finding and purchasing a rare book was the modern equivalent of stalking and slaughtering a mammoth. As a non-alpha male, it is satisfying to know that my relentless book browsing is the equivalent of hiding in the tall grass draped in rabbit fur, ready to spear an Evelyn Waugh.

dominating necessity – a relentless and burdensome joyless 'joy'. George A Romero was right with his shopping mall zombie apocalypse Dawn Of The Dead: we stumble blindly through artificially lit pleasure domes, hungrily lunging for sofas and laptop accessories. What lies behind our consumer lust? Unsurprisingly, dopamine, the neurotransmitter of delight that shapes so much of our behaviour, plays a major part. In 1995, University of Kentucky researchers observed that dopamine in a rat's brain surged when it found a new compartment in a cage. This delight in novelty is replicated when we find a new item in a shop,

which may also explain why we're more likely to make

preposterous purchases in novel places. Did vou really

need that porcelain camel from Marrakesh?

Within my lifetime, shopping has become a

But dopamine isn't the only thing responsible for our shopping obsession. Retailers are also increasingly aware of how to manipulate our spending behaviour. Smell is one of their most potent tactics. In Seoul in 2012, Dunkin' Donuts came up with an advertising campaign that would make Aldous Huxley blush. Air freshener dispensers were placed on selected buses in the city, and every time a Dunkin' Donuts jingle played, a coffee smell was squirted out. Sales at Dunkin' Donuts outlets near Seoul bus stops reportedly increased by 29 per cent as a result.

But scent doesn't always sell. A 'drink milk' campaign in San Francisco had bus shelters smelling of freshly baked chocolate chip cookies, but complaints soon put

an end to that. According to Rachel Herz, an expert on the psychology of smell, this was down to the odour not fitting the environment. It seems no one wants a chocolate bus stop – it creates suspicion rather than consumer desire. Believe it or not, the hubbub of a busy shop may be another factor that prompts us to spend more. A 2012 study in the Journal Of Consumer Research found that the

background noise in shopping malls, as long as it's not excessive, can prompt consumers to think abstractly and creatively, making them more likely to buy innovative products such as high-end trainers or flashy gadgets.

And we're not even safe in supermarkets. A whole host of tricks are designed to part us from our pennies, whether that's placing kidfriendly items at a lower levels, doing away with clocks so that we lose all concept of time, or positioning essential items in the remotest aisles so that we take the longest possible route before picking up our bread and milk.

In the end, is the stress of shopping really worth it? Psychologists have long known that memorable experiences tend to provide more happiness than material goods. In fact, a 2014 study led by psychologists at Cornell University found that even anticipating an experience was more pleasurable than waiting for a new possession. The novelty of a new phone that can store a million songs soon wears off, but a good short break near an attractive hill will keep giving with each return of that memory.

I know what I want for Christmas this year: a week without shopping. I'll wait until January to go out with my bow and arrow, and get that signed Carl Sagan first edition that I'm after. 6

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series The Infinite Monkey Cage bbc.in/1Lxp3QR

NEXT ISSUE: BEARDS

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

DECEMBER 2016 EDITED BY JAMES LLOYD

$\bigcirc 1$

MONKEY AROUND

MONKEY BUSINESS NATIONAL MUSEUM OF SCOTLAND, EDINBURGH, 9 DECEMBER 2016 – 23 APRIL 2017.

Say hello to Jasper and Toyah, two stars of a new show at the National Museum of Scotland. Jasper (right) is a male mandrill who lived at Southport Zoo until 1996; Toyah is a lion-tailed macaque who spent her days at Colchester Zoo before arriving at the museum in 2002.

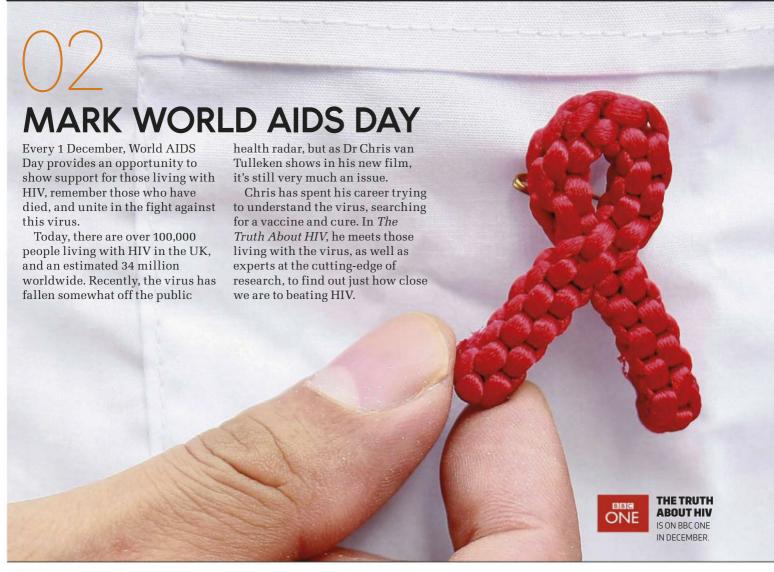
Now, they've been given a second lease of life. They're two of more than 50 taxidermy specimens commissioned especially for the *Monkey Business* exhibition, which shows

primates behaving as if they were in the wild. Joining Jasper and Toyah are other monkeys, apes, lemurs, lorises and bushbabies.

Visitors will get up-close to the primates in a simulated jungle, finding out how our hairy cousins evolved and adapted, how they communicate and form social groups, and how they use tools to get food. There's even a play area where visitors can unleash their inner chimp, by climbing, balancing and swinging to their hearts' content.











GET INTERACTIVE

Little ones running amok? Let them loose in Wonderlab, a fabulous new gallery at London's Science Museum that promises to inspire their imaginations and get them switched on to science. Spread across seven zones, there are 50 hands-on exhibits, as well as live shows in the 120-capacity theatre and while-you-wait experiments at the Chemistry Bar.

Looking like something dreamt up by Willy Wonka, visitors to Wonderlab can whizz down giant slides, watch lightning strike before their eyes, peer into a mirrored 'infinity box', have a go at water drop photography, and explore a huge model of the Solar System. And while the kids are busy discovering the mysteries of the cosmos, why not sneak off to the Shake Bar for a dairy treat. Everyone's a winner...

SOLVE SOME PROBLEMS

For his new book, ALEX BELLOS has searched far and wide for the world's most addictive and mind-bending puzzles. Here are 10 teasers to get you started...

CAN YOU SOLVE MY PROBLEMS?

BY ALEX BELLOS IS OUT 3 NOVEMBER (£14.99, GUARDIAN FABER)



The diagrams below show three different views of the same cube. Which letter is on the face opposite U?

A:**I** B:**P**

(.K

 $D \cdot M$

E:0



What do the following words have in common?

> **ASSESS BANANA DRESSER GRAMMAR POTATO REVIVE UNEVEN VOODOO**



Puzzle scholar David Singmaster noticed the following pattern while invigilating an exam. He did not accidentally get the T-key jammed on his laptop.

What's the next letter?



Complete the word below. The given letters must appear in that order in the final word, with no letters in between.

H₀



Amy, Ben and Chris are standing in a row. If Amy is to the left of Ben and Chris is to the right of Amy, which of these statements must be true?

A: Ben is furthest to the left

B: Chris is furthest to the right

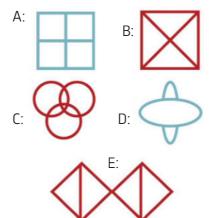
C: Amy is in the middle

D: Amy is furthest to the left

F. None of the statements A.B. C. D is true



Which of these diagrams can be drawn without taking the pen off the page, and without drawing along a line that's already been drawn?





Pinocchio's nose is 5cm long. Each time he tells a lie his nose doubles in length. After he has told nine lies, his nose will be roughly the same length as a:

A: **DOMINO**

B: TENNIS RACKET

C: SNOOKER TABLE

D: TENNIS COURT

E: FOOTBALL PITCH

Jasper Jason works for local radio. This is his business card.



Can you spot the pattern?



What letter comes next to complete this sequence?

OUEHRA



The word 'thirty' contains 6 letters, and $30 = 6 \times 5$. Similarly, the word 'forty' contains 5 letters, and $40 = 5 \times 8$. Which of the following is not a multiple of the number of letters it contains?

A: SIX

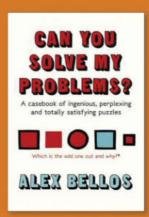
B: TWELVE

C: EIGHTEEN

D: SEVENTY

E: NINETY

PUZZLES 1, 5, 6, 7 AND 10 WERE KINDLY SUPPLIED BY THE UK MATHEMATICS TRUST (WWW.UKMT.ORG.UK)



LEWIS DARTNELL SHARES HIS FAVOURITE SPOTS IN LONDON



ondon is my city and I'm proud of it, not just for its incredible history of science and innovation, but for the astoundingly diverse, multicultural and tolerant environment it is today. Londoners are spoilt by the selection of world-class science and technology museums and exhibitions, such as the Science Museum, Natural History Museum and the Royal Institution. But the city has some less familiar spots that are really interesting.

HORNIMAN MUSEUM AND GARDENS 1 deserves to be much better known. It's an overwhelmingly rich collection of international, cultural and anthropological artefacts, as well as natural history specimens.

I love the **ROYAL OBSERVATORY GREENWICH 2**, with its huge planetarium dome. It's not only the home of the prime meridian line (and thus also the origin of Greenwich Mean Time), but also offers a superb view back across London's Docklands, Canary Wharf and the Millennium Dome.

Another great place is **THE MONUMENT 3**, which commemorates the Great Fire of London of 1666.

Christopher Wren and Robert Hooke designed this impressive column, which is also a giant scientific instrument. The central shaft is a zenith telescope, and was used in various experiments. It sits atop an underground laboratory.

For an excellent pie and chips, I head to the JOHN SNOW 3. This pub overlooks the memorial water pump that's dedicated to the man himself, who was an eminent 19th-Century physician and the father of public health. I wrote the medicine chapter of my last popular science book, *The Knowledge: How To Rebuild Our World After An Apocalypse* sat in this pub.

My favourite spot for people watching and pondering is sat on a wall in TRAFALGAR SQUARE 5 — it's a great place to watch tourists take selfies as locals hurry by. But my favourite thing to do in London is to cycle across WATERLOO BRIDGE 5. You've got incredible views in both directions along the Thames at all the iconic riverside landmarks. With a soundtrack in your ears you feel like you're in the opening scene of your own movie! 6

OHORNIMAN MUSEUM

This museum is home to a music gallery, aquarium, nature trail, and more.

100 London Road, Forest Hill, SE23 3PO

horniman.ac.uk

2 ROYAL OBSERVATORY GREENWICH

The birthplace of Greenwich Mean Time. Blackheath Avenue, SE10 8XJ rmg.co.uk/royal-observatory

3THE MONUMENT

Climb up this landmark's 311 spiral steps for a stunning view of the city. Fish St Hill, EC3R 8AH themonument.org.uk

3 JOHN SNOW PUB

This pub is named after the physician who traced the 1854 cholera outbreak to a water pump on this street.

39 Broadwick Street, W1F 9QJ

5TRAFALGAR SOUARE

Named after the Battle of Trafalgar, the square houses Nelson's Column. Westminster, WC2N 5DN

3WATERLOO BRIDGE

Opened in 1945, this bridge across the Thames offers one of London's most iconic views.

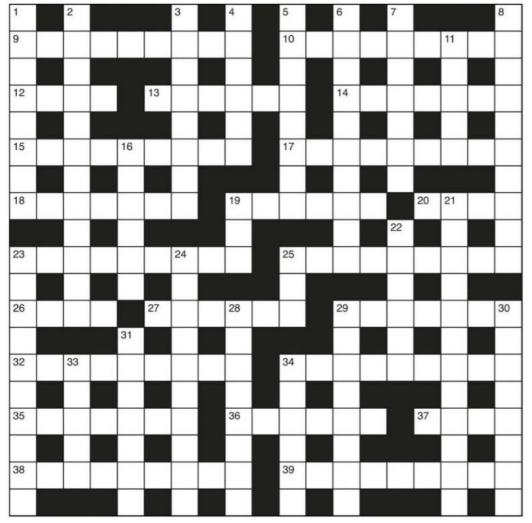
Prof Lewis Dartnell is a research scientist, presenter and author. He holds a professorship in science communication at the University of Westminster.



ILLUSTRATION: TONWEN JONES

THE BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 9 A necrotic form of growth (9)
- 10 Finished with equestrian bit of a bumper (9)
- 12 Rings with greeting from somewhere in America (4)
- 13 A complaint, seeing one rodent (6)
- 14 At home, Linus manufactured a hormone (7)
- 15 Mineral from meteor somehow gets illuminated (9)
- 17 Temperature measurement of my tastier recipe (9)
- 18 Neptune's missile (7)
- 19 Firework found in salad (6)
- 20 Grave inference about vital supplier (4)

- 23 Addams family girl's time (9)
- 25 Firm politician with single book part (9)
- 26 Went off amphibian (4)
- 27 Prophet round to clear confusion (6)
- 29 Flexible cats lie around (7)
- 32 Old enemy has new tail to clean thoroughly (9)
- 34 Room left in distant base (9)
- 35 Student to turn to doctor in the past for an ache (7)
- 36 Show and hide (6)
- 37 Pushy people get publicity (4)
- 38 Cares more about bit of skeletal muscle (9)
- 39 Copy keys one to smirk about (9)

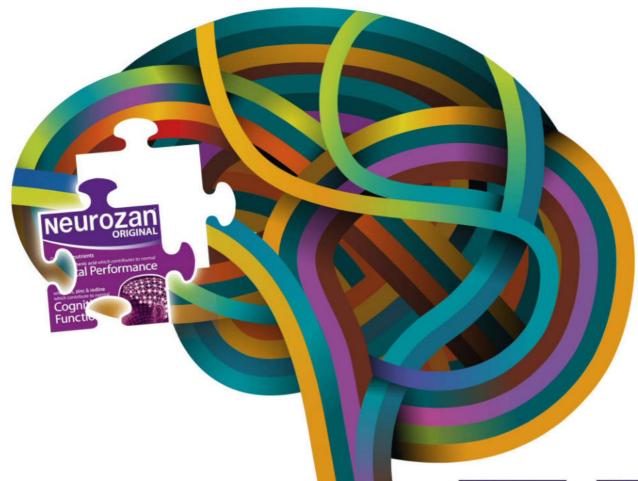
DOWN

- Stop cooking toast in pressure regulator (8)
- 2 Involved opportunity where one is working (6,6)
- 3 Labour suiting new tongue specialist (8)
- 4 Ruin form with small point and take cover (6)
- 5 This coil works on the entire person (8)
- 6 Moist puree used for bone covering (10)
- 7 Experts honour a bit of a spider (7)
- 8 It's relatively easy to tie (6,4)
- 11 Daughter left out some pottery (5)
- 16 Batsman useful in the kitchen (6)
- 19 Beam at a fish (3)
- 21 Oils secretly used in cosmetic treatment (12)
- 22 Note colour without new salad ingredient (6)
- 23 Adult wrens display desire to travel (10)
- 24 Dream got weird, with space for plant tissue (10)
- 25 Evidence left out as a signal (3)
- 28 Revolutionary ship has soldiers in pieces (8)
- 29 Woman has rewritten scene vanish (8)
- **30** Provide with article such as a tube for drainage (8)
- 31 Henry II's wife has Nero running round field (7)
- 33 Supporter adds iron to rum cocktail (5)
- 34 Untidy person's got some neck (6)

ANSWERS

For the answers, visit bit.ly/TheNumberGames
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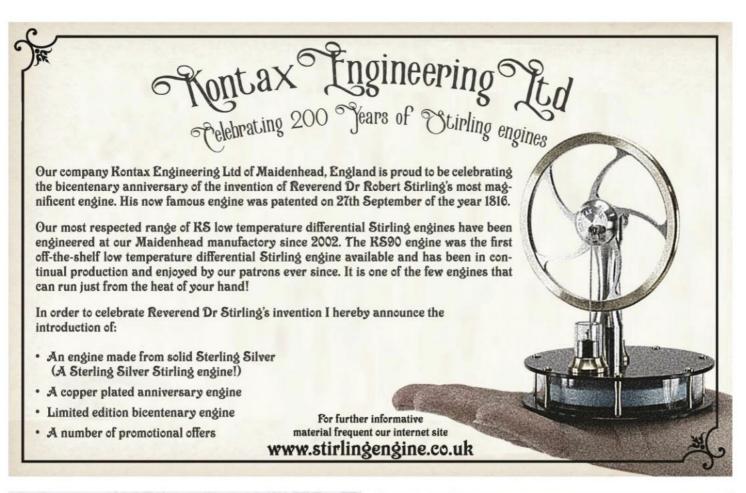




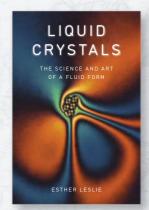








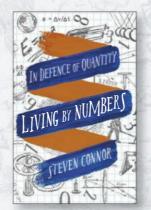




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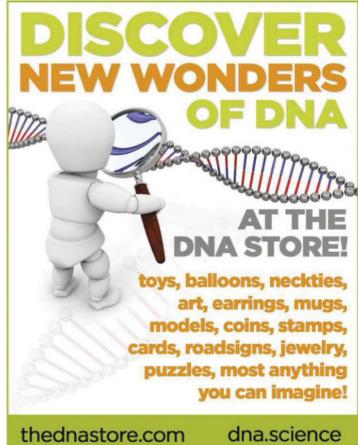
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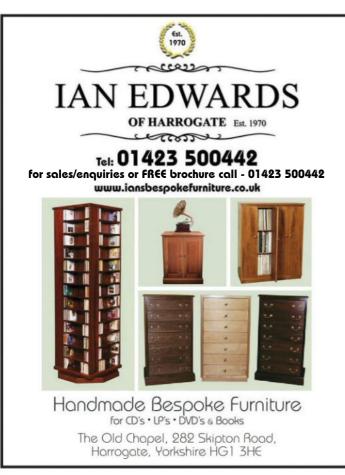
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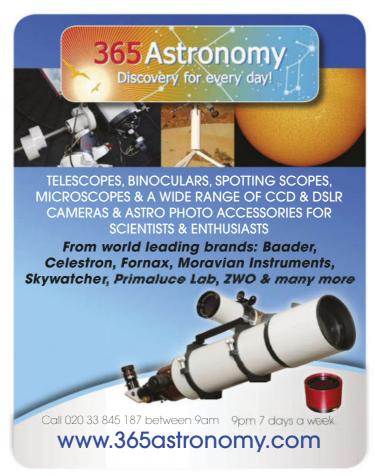


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EXPLORATION

The deep

More people have set foot on the Moon than explored the deepest realms of our oceans, but that could all be about to change. We profile the pioneers who are set to venture into the abyss.

RAZZMATAZZ

WHY WE LOVE TO DANCE

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HUMAN BODY

YOUR SECOND BRAIN

If you thought the only brain in your body is in your skull, think

again. Scientists are discovering that the network of neurons in our gut plays a crucial role in our mood, health, and even decision-making.



TECHNOLOGY

THE ROBOTS THAT LEARN BY WATCHING YOU

Google, Apple, Amazon and Facebook are all building robots and AI that learn by watching our habits. How do they do it, and where will it lead?





"We have certain plants that are banned in the public realm"

Prof Kathy Willis, the director of science at Kew's Royal Botanic Gardens, tells Helen **Pilcher** about her love for plants... and why her own garden won't win any awards

My mum was evacuated from London to the countryside during WWII. She often spoke happily about those times; about spending time outside and learning the names of plants. Then the older I got, the more interested in plants I became.

My big passion as a child wasn't plants. It was singing. Later on I had to choose between going to university or music college. I opted for university but carried on singing in a semi-professional capacity.

If I wasn't a scientist, I'd like to be a singer in the English National Opera. I'd be on the back row in a huge costume playing some old crone.

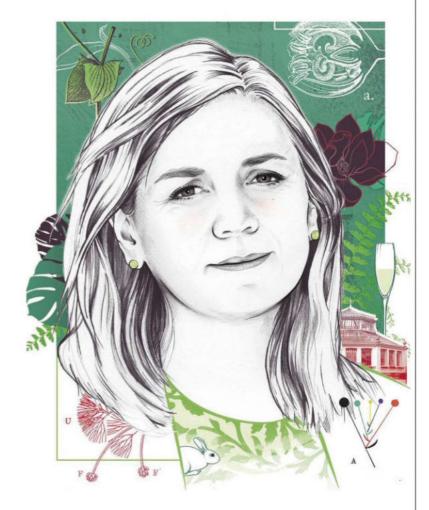
The job is exhausting but exhilarating - and when I look back on my life, I think my time at Kew will be the thing I am most proud of. Kew really is an extraordinary place to work. There are hundreds of scientists, over eight million herbarium specimens, more than 45,000 plant DNA samples and over two billion seeds in the millennium seed bank.

We have some extremely rare plants at Kew. ${
m The}$ Temperate House is reopening in 2018, which will house endangered plants that most people will never get the chance to see growing in the wild. For example, we have a coffee plant from Mauritius that is one of the last few surviving specimens of its kind.

If any illegal plants come into Heathrow, they end up in our quarantine facility. We have some plants that are banned in the public realm. We are the UK's scientific authority for the trade in illegal plants.

We're seeing a massive decline in students studying plant **science.** It's a real problem and one of the reasons I'm passionate about making plant science interesting. I give a lot of talks, have made radio programmes, and this year we ran our first science festival at Kew. Thankfully, it was a big success.

Did you know that the strawberries we eat contain whole extra copies of the genome and can be up to four times bigger than wild strawberries? It's a naturally occurring phenomenon called polyploidy. Most of the crops we eat are polyploids. It's a feature that tends to make plants bigger and more resilient.



As well as my job at Kew, I teach and manage a research group at Oxford University. And there's certainly plenty of variety, talking to academics, students, government ministers and small children. It's busy, but I've always worked on the basis that you should live life to the full because you spend a lot of time dead!

Prof Kathy Willis is a plant scientist and the director of science at Kew Botanic Gardens.

DISCOVER MORE



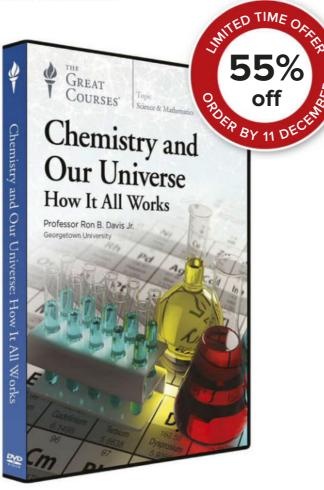
To listen to an episode of The Life Scientific with Kathy Willis, visit

bbc.in/1ksPobh **NEXT ISSUE: KEN LIBBRECHT**

My downtime is spent with my family and our dog, at the gym with my daughter, and the occasional glass of Prosecco.

I enjoy gardening, but our garden at home might not win any prizes for horticulture! It has to double up as a football practice ground for my 12-year-old son and his friends, and home to our two rabbits. 6





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